Days at Home as an Outcome Measure after Surgery

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-015828
Article Type:	Research
Date Submitted by the Author:	03-Jan-2017
Complete List of Authors:	Myles, Paul; Alfred Hospital and Monash University, Anaesthesia and Perioperative Medicine Shulman, Mark; Alfred Hospital Heritier, Stephane; School of Public Health and Preventive Medicine, Monash University, Department of Epidemiology and Preventive Medicine Wallace, Sophie; Alfred Hospital McIlroy, David; Alfred Hospital, Department of Anaesthesia and Perioperative Medicine McCluskey, Stuart; University Health Network, Anesthesia and Pain Medicine Sillar, Isabella; Alfred Hospital Forbes, Andrew; Monash University
Primary Subject Heading:	Anaesthesia
Secondary Subject Heading:	Surgery, Epidemiology
Keywords:	STATISTICS & RESEARCH METHODS, outcome, perioperative medicine, Clinical trials < THERAPEUTICS

Days at Home as an Outcome Measure after Surgery

Paul S. Myles,[1,2,3] Mark A. Shulman,[1] Stephane Heritier,[3] Sophie Wallace,[1] David R. McIlroy,[1,2] Stuart McCluskey,[4] Isabella Sillar,[2] Andrew Forbes[3]

[1]Department of Anaesthesia and Perioperative Medicine, Alfred Hospital, Melbourne, Australia
[2]Department of Anaesthesia and Perioperative Medicine, Monash University, Melbourne, Australia
[3]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia
[4]Toronto General Hospital and University of Toronto, Toronto, ON, Canada

ADDRESS FOR CORRESPONDENCE
Paul S. Myles
Professor and Chair
Department of Anaesthesia and Perioperative Medicine
Alfred Hospital, Commercial Road, Melbourne, Victoria, 3004, Australia

Email: p.myles@alfred.org.au

Word count: 2745

Competing interest statement - All authors declare that the answer to the questions on the competing interest form are all No and therefore have nothing to declare.

Funding - The Australian and New Zealand College of Anaesthetists; and the Australian National Health and Medical Research Council Practitioner Fellowship (Prof Myles).

ABSTRACT

OBJECTIVE To evaluate "days at home up to 30 days after surgery" (DAH_{30}) as a patient-centred outcome measure.

DESIGN Prospective cohort study.

DATA SOURCE Using clinical trial data (7 trials, 2109 patients) we calculated DAH_{30} from length of stay, re-admission, discharge destination, and death up to 30 days after surgery.

MAIN OUTCOME The association between DAH_{30} and serious complications after surgery.

RESULTS One or more complications occurred in 263 of 1846 (14.2%) patients, including 19 (1.0%) deaths within 30 days of surgery; 245 (11.6%) patients were discharged to a rehabilitation facility and 150 (7.1%) were readmitted to hospital within 30 days of surgery. The median DAH_{30} was significantly less in older patients (P<0.001), those with poorer physical functioning (P<0.001), and in those undergoing longer operations (P<0.001). Patients with serious complications had less days at home than patients without serious complications (20.5 [95% CI, 19.1 to 21.9] vs 23.9 [95% CI, 23.8 to 23.9] P<0 .001), and had higher rates of readmission (16.0% vs. 5.9%; P < 0.001). After adjusting for patient age, sex, physical status and duration of surgery, the occurrence of postoperative complications was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.001).

CONCLUSIONS DAH_{30} is a valid and readily-obtainable generic patient-centred outcome measure. It is an ideal outcome measure for perioperative clinical trials.

Strengths and limitations of the study

- This study integrates length of stay, re-admission, discharge destination, and early deaths after surgery into a single outcome metric, “days at home up to 30 days after surgery” (DAH_{30})
- DAH_{30}, as numerical data, provides greater statistical power and so can reduce the sample size required to evaluate new treatments
- DAH_{30} is an ideal, patient-centred outcome measure for perioperative clinical trials and quality assurance activities
- DAH_{30} can also be used to evaluate the outcome of hospital treatment for medical conditions (e.g. exacerbation of heart failure or chronic obstructive pulmonary disease)

Introduction

Surgery and other interventional procedures are intended to relieve symptoms and in many cases prolong life. But surgery is not risk-free; perioperative complications can impair patient recovery resulting in prolonged hospitalization, short or longer term disability, and sometimes poor survival. A wide variety of outcome measures have been used to quantify each of these aspects of the postoperative experience but few provide a broad, patient-centred perspective of effective and efficient care;[1] these are needed to better inform the current shift towards value-based healthcare.[2 3]

Patient-centred care requires clinicians to consider outcomes that matter most to patients. That is, the patient's experience of their illness, quality of life, and functioning; their values, preferences and goals for health care.[4] Loss of the ability to live independently is a major concern for the elderly;[5 6] it is clearly a patient-centred outcome, and has been associated with postoperative readmissions and death after hospital discharge.[5]

Specific peri-procedural complications such as surgical site infection, respiratory failure, delirium, and myocardial infarction are clearly important to patients and physicians alike, but reliable and consistent detection is problematic. In any case such information is an incomplete description of the overall success of surgery and other perioperative care, and does not describe the impact of such complications on functioning and need for institutionalization. Similar challenges occur when nominating endpoints in clinical trials, including a lack of standardisation,[7] need for adjudication, and uncertainty about the overall health impact of each endpoint on a patient's recovery. There is a growing acceptance that

outcome measures used in clinical trials should be determined in partnership by patients and physician-researchers, aiming to identify outcomes that are important to patients.[8]

"Days alive and out of hospital" has been shown to be a readily quantifiable and patient-centred outcome measure in some chronic cardiovascular conditions such as heart failure and atrial fibrillation,[9-11] and in geriatric medicine,[12] but it has not been used as an outcome measure in perioperative trials. Home discharge has been proposed as a proxy for a patient's recovery after surgery,[13] and is estimated when using the American College of Surgeons' Surgical Risk Calculator,[14] but this does not account for readmissions or early deaths, although the latter collects and reports some of this information.[15]

Our own work and that of others have shown that early return home after surgery,[6 16-18] and medical illnesses such as stroke,[19 20] is highly valued by patients but could be undermined if the patient were to be transferred to another type of nursing facility. A more favourable perioperative outcome measure should account for both the initial hospital stay associated with the index surgery, rehospitalisation due to post-discharge complications, discharge to institutional care, and early deaths.

We thus chose to evaluate the utility of "days (alive and) at home" within 30 days of surgery (DAH_{30}) in the surgical/perioperative setting as a patient-centred outcome measure for perioperative clinical trials and quality improvement activities. Our hypothesis was that DAH_{30} would be lower in higher risk patients, those undergoing more extensive surgery, and in those with complications after surgery.

Methods

This manuscript was written in adherence to the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement.[21]

Study Design and Data Sources

Data were obtained from each of seven recently completed clinical trials that prospectively enrolled patients undergoing various types of elective and emergency surgery at the Alfred Hospital in Melbourne, Australia. The cohort consisted of four multicentre randomised trials and three before-and-after studies (see Table S1 in the Supplementary Appendix).[22-29] For each trial we collected a comparable set of patient demographic and perioperative characteristics, and clinical outcome measures, including complete hospital discharge, discharge destination (home, rehabilitation facility, nursing home) and re-admission data. All but one study[28] prospectively recorded re-admission data; for the latter study we could obtain this information retrospectively from our hospital information system. Both the present study and each of the original trials received institutional ethics committee approval.

Patients

Patients 18 years and older undergoing an elective or non-elective inpatient operation enrolled in one of the aforementioned trials were included. Study inclusion criteria were established for the original studies and typically identified those at increased risk of postoperative complications. In all cases patients provided informed consent before enrolment in the original trials.

Patient involvement

Hospital patients have previously indicated the importance of returning home after hospitalisation for medical or surgical conditions, [6 16-20] but we did not involve patients or their carers in the design or conduct of this study.

Risk Factors and Outcomes

Perioperative data included patient demographics, comorbidity, functional status, type and duration of surgery, hospital length of stay, hospital readmission(s), and in all but one study[28] we prospectively collected selected complications at 30 days after surgery: wound infection, myocardial infarction, stroke, pulmonary embolism, cardiac arrest, and death.

Hospital discharge data were used to calculate hospital length of stay. Whether the patient was discharged from hospital to their home or to a nursing facility was obtained from the electronic medical record, but for those admitted to a rehabilitation facility we were unable to ascertain the number of days admitted before eventual discharge home. For those readmitted to hospital we combined the original length of stay with subsequent hospital stay(s) to calculate total length of stay within 30 days postoperatively.

DAH_{30} was calculated using mortality and hospitalisation data from the date of the index surgery (Day 0). For example, if a patient died on day 2 after their surgery, they were assigned 0 DAH_{30}, if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they were assigned 20 DAH_{30}. We were unable to reliably collect secondary length of stay for rehabilitation facilities - we thus did a secondary analysis assuming the length of stay in a rehabilitation facility was 5 extra days. That is, $DAH_{30\text{-rehab}}$ was calculated as DAH_{30}-5 in a secondary analysis.

For the multicentre trials,[22-24] a 12-lead electrocardiograph was recorded preoperatively and on day 1 and 3 after surgery. Blood for troponin (or if unavailable, creatine kinase-myocardial band) measurement was collected at 6 to 12 hours after surgery and on the first three postoperative days. In all trials laboratory tests were otherwise ordered if clinically indicated. Each complication was defined within the original study protocol and in all cases a consistent definition was used. In brief, surgical site infection was confirmed if associated with purulent discharge, with or without a positive microbial culture; or pathogenic organisms isolated from aseptically obtained microbial culture,[30] although the most recent trial[27] included documentation of a physician's diagnosis in this definition.[31] Pneumonia was confirmed by a new pulmonary infiltrate reported by chest x-ray or computerized tomography, in association with at least one of: temperature >38°C, white cell count >12,000/ml, or positive sputum culture that was not heavily contaminated with oral flora or that corresponded with positive blood cultures. Myocardial infarction was defined according to the third universal definition,[32] requiring elevated cardiac biomarker plus at least one of the following: (i) ischaemic symptoms, (ii) pathological Q waves, (iii) electrocardiographic changes indicative of ischemia, (iv) coronary artery intervention or (v) new wall motion abnormality on echocardiography or scanning; or autopsy finding of myocardial infarction. The threshold for significant elevated troponin was the hospital laboratory's 99th percentile of a normal reference population (upper reference limit), according to recent recommendations.[33] Stroke was confirmed if a new neurological deficit persisting for at least 24 hours, verified by neurologist assessment and/or computerized tomography or magnetic resonance imaging.

Statistical Analysis[34 35]

Data were first merged and checked for inconsistencies. Patient age was grouped into 10-year categories, and hourly cut-points for duration of surgery (2, 3, and 4 h) were created to generate approximately similar group sizes and facilitate clinical interpretation. DAH_{30} was analysed using quantile regression.[36] This approach allows the modelling of any quantile of a continuous endpoint, here DAH_{30}, as a linear combination of the covariates. As DAH_{30} is left skewed with a spike at zero, it is more relevant to model the median (or alternatively, the 75th percentile) that is closer to the major distribution mode and directly interpretable. No assumption on the true distribution of the endpoint is required. Raw and adjusted medians and their 95% confidence intervals (CIs) obtained by bootstrapping with 1000 replicates were reported for key predictors. The adjusted models included age by 10-year categories, sex, ASA, surgery time (< 2h, 2.0 - 2.99, 3.0 -3.99, ≥4.0). A global test of effect of any key predictor was carried out using a quasi-likelihood ratio test.[37] Quantile regression was also used to test median differences between those with and without complications, and by postoperative complications. Supplementary analyses were done for Q3. All analyses were done using Stata 14.0 except the LRT analysis only available in SAS. All tests were two-sided and performed at level α=0.05; no correction was made for multiple comparisons.

Results

A total of 2109 eligible patients 18 years and older were enrolled into clinical trials and underwent inpatient operations at the Alfred Hospital between March 2006 and September 2016. The number of patients enrolled in each of the trials is detailed in the Supplement (Supplementary Table 1). The cohort included 1427 male patients (67.7%) with a mean (SD) age of 65 (12) years who underwent a range of inpatient operations (Table 1). Most operations were cardiac surgical procedures (679 [32.2%]), followed by general (489 [23.2%]), urologic (315 [14.9%]), and neurosurgical procedures (220 [10.4%]).

There was a bimodal, skewed distribution of DAH_{30} (Figure 1). The spike at zero consisted of 19 patients (1.0%) that died, and 40 patients remaining in hospital at least 30 days after surgery. DAH_{30} and rates of admission to a rehabilitation centre varied according to type of surgery (Table 2).

One or more complications occurred in 263 (14.2%) patients. Overall, 245 (11.6%) patients were admitted to a rehabilitation facility and 150 (7.1%) were readmitted within 30 days of surgery. The median DAH_{30} was 23.7 (95% CI, 23.5 to 24.0), but this varied according to type of surgery (Table 1).

The median DAH_{30} was significantly less in older patients, current smokers, diabetics, those with poorer physical functioning, and undergoing longer operations (Table 2). These associations remained after adjustment for all of these covariates and patient sex (Table 2). The individual complications of myocardial infarction, stroke, pulmonary embolism, and surgical site infection were each associated with shorter DAH_{30} (Table 3) in a raw analysis.

Hospital readmission was also a factor, decreasing median DAH_{30} when compared with those not readmitted to hospital, 17.9 (95% CI, 16.3 to 19.5) vs 23.9 (95% CI, 23.8 to 23.9), respectively (P<0.0001).

After adjusting for patient age, sex, ASA physical status and duration of surgery, the occurrence of any postoperative complication was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.0001).

Supplementary Analyses

The above findings were consistent when analysing the 3rd quartile distributions and differences (Tables S2-S4 in the Supplementary Appendix), and after accounting for the additional loss of days at home because of admission to a rehabilitation centre (Tables S5 and S6 in the Supplementary Appendix).

Discussion

We found that DAH_{30} is a valid and readily-obtainable patient-centred outcome measure that could be used to better inform patients and physicians when planning surgery. Unlike previous related measures, DAH_{30} accounts for each of delayed hospital discharge because of postoperative complications, discharge to a rehabilitation centre or other post-acute care nursing facility, rehospitalisations, and postoperative deaths. It thus captures much of the surgical experience, integrating efficacy, quality and safety, and thus reflecting value-based care. It can also be risk-adjusted for bench-marking purposes. DAH_{30} will be maximized when patients recover free of complications after surgery, with optimal comfort and functioning - aligning with patient values and preferences, and goals for health care.[4]

The US has a triple aim of improving the healthcare system: improving the patient experience of care, improving the health of populations, and reducing per capita costs of healthcare.[38] DAH_{30} seems to be useful, generic metric in this regard.[39] DAH_{30} is a measure of the overall burden of care, both in hospital and post-discharge. The perceived success of a hospital discharge plan as perceived by the patient and their principal carer depends on clear communication and meeting expectations.[40] DAH_{30} offers transparency and opportunities for benchmarking performance, both of which are important components of quality improvement.[1 3] It may influence alternative payment contracts for hospitals.

Postoperative complications add to hospital costs and increase length of stay.[41] Higher episode payments at "lower-quality" hospitals have been attributed to higher rates of complications, 30-day readmissions, and post-discharge ancillary care.[41] Serious postoperative complications are both strongly associated with readmission,[5 17] increasing the risk by 6.7-fold, and loss of independence.[5] Readmission is a frequent, costly, and sometimes life-threatening event that is associated with gaps in follow-up care.[15 17 42] Readmission after surgery is thus an established quality indicator. Trends in readmissions suggest that US hospitals are responding to incentives to reduce readmissions under the Affordable Care Act.[43 44] Hospital readmission rates are not highly correlated with mortality rates, [45] so they offer an independent and more sensitive measure of quality. Even though some readmissions are due to chronic medical conditions,[42] optimal perioperative care should keep these to a minimum and such improvements should be reflected in more DAH_{30}.

Enhanced recovery after surgery programs are designed to reduce complications and shorten length of stay. But this sometimes comes at the cost of increased hospital re-admissions.[46 47] The measurement and reporting of DAH_{30} would identify this and hopefully encourage further quality improvement. Planned discharge to a rehabilitation facility sometimes forms part of an enhanced recovery pathway, and in any case may not be seen by the patient or their family as indicating a poor outcome. Therefore, calculation of DAH_{30} in some studies could incorporate days spent in a rehabilitation facility as equivalent to being home. In contrast, unplanned admission to a rehabilitation facility would indicate poor care or adverse outcome, and this should be retained in the calculation of DAH_{30}. Care should be taken to avoid missing out-of-network hospitalizations, particularly if relying on hospital system electronic medical records. The latter will otherwise enhance the efficiency of data collection.

Composite endpoints used in perioperative trials are often flawed,[48-50] typically used to increase the number of events in order to enhance statistical power. DAH_{30}, as a numerical patient-centred measure, provides more statistical power, can be reliably measured and has direct patient-centredness. Although some postoperative complications and poor survival can manifest many months after surgery in those recovering from major surgery or critical illness,[29 51 52] extending measurement out to 90 days after surgery (i.e. DAH_{90}) may not necessarily provide new or different information because the extra burden and costs of further data collection may outweigh the benefits of the extra information obtained. In addition, disease progression or other aspects of life may confound outcome evaluation of perioperative care.

Our study has several limitations. First, postoperative in-hospital deaths have a major influence on the calculation of DAH_{30}; this is arguably appropriate because perioperative studies should weight this as the most extreme adverse outcome. More sophisticated modelling could jointly model the risk of death and DAH_{30} in those discharged alive, and such modelling would be particularly important if the in-hospital mortality rate is moderate or greater. Second, different health care settings can be expected to have varied casemix and hospital discharge processes, and hospital discharge may be delayed because of social and process issues unrelated to complications or quality of care. DAH_{30} should therefore be risk-adjusted.[53] Third, DAH_{30} doesn't provide specific information on which aspects of in-hospital or post-discharge management influences where patients reside after hospitalization, or the post-discharge use and effectiveness of family physician or other health care resources. Fourth, DAH_{30} is an overall measure of recovery profile and does not inform us about specific complications, level of functioning or wellbeing. Such aspects should also be included when conducting outcome studies. Fifth, obtaining accurate data on days spent in a rehabilitation facility relies on further follow-up or accurate electronic records. Future studies using DAH_{30} should prospectively plan to reliably obtain such data.

CONCLUSIONS

DAH_{30} is a valid and readily-obtainable, generic, patient-centred outcome measure that can better inform patients and physicians when planning surgery. It is a suitable outcome measure for both quality improvement and perioperative clinical trials. DAH_{30} accounts for prolonged hospital stay, discharge to any post-acute care nursing facility, rehospitalizations, and early deaths. It thus captures much of the patient-centred experience, and will be maximal when effective and efficient care is achieved.

Contributor statement: PM designed the study, oversaw the ethics application, devised the statistical analysis plan, and drafted and revised the paper. He is guarantor. MS provided intellectual input into the study design, and drafted and revised the paper. SH analysed the data and drafted and revised the paper. SW prepared the ethics application, monitored the data entry and checking, and drafted and revised the paper. DM provided intellectual input into the study design, and drafted and revised the paper. SM provided intellectual input into the study design, and drafted and revised the paper. IS retrieved and entered all study data, and revised the paper. AF contributed to the statistical analysis, and drafted and revised the paper.

Transparency declaration: The lead author* affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Acknowledgment: The authors would like to thank the study participants for their interest and preparedness to consent to the original trials. PM is supported in part by Practitioner Fellowships from the Australian National Health and Medical Research Council (NHMRC).

Funding: This work was supported by the Australian NHMRC, the New Zealand Health Research Council, and the Australian and New Zealand College of Anaesthetists, and Monash University (Melbourne, Australia).

Additional data: No additional data available.

Competing interests: None of the authors have any conflicts of interest

Ethics approval: This trial has been approved by the Ethics Committees of Alfred Health, Melbourne, Australia.

References

1. Austin JM, McGlynn EA, Pronovost PJ. Fostering Transparency in Outcomes, Quality, Safety, and Costs. *Jama* 2016 doi: 10.1001/jama.2016.14039 [published Online First: 2016/09/27]
2. Lynn J, McKethan A, Jha AK. Value-Based Payments Require Valuing What Matters to Patients. *JAMA* 2015;314(14):1445-6. doi: 10.1001/jama.2015.8909
3. Porter ME. What is value in health care? *N Engl J Med* 2010;363(26):2477-81. doi: 10.1056/NEJMp1011024 [published Online First: 2010/12/15]
4. Lavallee DC, Chenok KE, Love RM, et al. Incorporating Patient-Reported Outcomes Into Health Care To Engage Patients And Enhance Care. *Health Aff (Millwood)* 2016;35(4):575-82. doi: 10.1377/hlthaff.2015.1362 [published Online First: 2016/04/06]
5. Berian JR, Mohanty S, Ko CY, et al. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg* 2016;151(9):e161689. doi: 10.1001/jamasurg.2016.1689 [published Online First: 2016/07/14]
6. Fried TR, Bradley EH, Towle VR, et al. Understanding the treatment preferences of seriously ill patients. *N Engl J Med* 2002;346(14):1061-6. doi: 10.1056/NEJMsa012528
7. Goldfarb M, Drudi L, Almohammadi M, et al. Outcome Reporting in Cardiac Surgery Trials: Systematic Review and Critical Appraisal. *J Am Heart Assoc* 2015;4(8):e002204. doi: 10.1161/jaha.115.002204 [published Online First: 2015/08/19]
8. Chalmers I, Clarke M. Outcomes that matter to patients in tombstone trials. *Lancet* 2001;358(9293):1649. doi: S0140673601066892 [pii] [published Online First: 2001/11/22]
9. Ariti CA, Cleland JG, Pocock SJ, et al. Days alive and out of hospital and the patient journey in patients with heart failure: Insights from the candesartan in heart failure: assessment of reduction in mortality and morbidity (CHARM) program. *Am Heart J* 2011;162(5):900-6. doi: 10.1016/j.ahj.2011.08.003
10. Wasywich CA, Gamble GD, Whalley GA, et al. Understanding changing patterns of survival and hospitalization for heart failure over two decades in New Zealand: utility of 'days alive and out of hospital' from epidemiological data. *Eur J Heart Fail* 2010;12(5):462-8. doi: 10.1093/eurjhf/hfq027
11. Xian Y, Wu J, O'Brien EC, et al. Real world effectiveness of warfarin among ischemic stroke patients with atrial fibrillation: observational analysis from Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research (PROSPER) study. *BMJ* 2015;351:h3786. doi: 10.1136/bmj.h3786
12. Ellis G, Whitehead MA, Robinson D, et al. Comprehensive geriatric assessment for older adults admitted to hospital: meta-analysis of randomised controlled trials. *Bmj* 2011;343:d6553. doi: 10.1136/bmj.d6553 [published Online First: 2011/10/29]
13. Hyder JA, Hirschberg RE, Nguyen LL. Home discharge as a performance metric for surgery. *JAMA Surg* 2015;150(2):96-7. doi: 10.1001/jamasurg.2014.1725 [published Online First: 2014/12/05]
14. Hyder JA, Wakeam E, Habermann EB, et al. Derivation and validation of a simple calculator to predict home discharge after surgery. *J Am Coll Surg* 2014;218(2):226-36. doi: 10.1016/j.jamcollsurg.2013.11.002
15. Merkow RP, Ju MH, Chung JW, et al. Underlying reasons associated with hospital readmission following surgery in the United States. *JAMA* 2015;313(5):483-95. doi: 10.1001/jama.2014.18614
16. Boney O, Bell M, Bell N, et al. Identifying research priorities in anaesthesia and perioperative care: final report of the joint National Institute of Academic Anaesthesia/James Lind Alliance Research Priority Setting Partnership. *BMJ Open* 2015;5(12):e010006. doi: 10.1136/bmjopen-2015-010006 [published Online First: 2015/12/18]
17. Hinami K, Bilimoria KY, Kallas PG, et al. Patient experiences after hospitalizations for elective surgery. *Am J Surg* 2014;207(6):855-62. doi: 10.1016/j.amjsurg.2013.04.014

18. Burns KE, Jacob SK, Aguirre V, et al. Stakeholder Engagement in Trial Design: Survey of Visitors to Critically Ill Patients Regarding Preferences for Outcomes and Treatment Options during Weaning from Mechanical Ventilation. *Ann Am Thorac Soc* 2016;13(11):1962-68. doi: 10.1513/AnnalsATS.201606-445OC [published Online First: 2016/09/07]
19. Hannah D, Lindholm B, Maisch L. Certain uncertainty: life after stroke from the patient's perspective. *Circ Cardiovasc Qual Outcomes* 2014;7(6):968-9. doi: 10.1161/CIRCOUTCOMES.114.001315
20. Xian Y, O'Brien EC, Fonarow GC, et al. Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research: Implementing the patient-driven research paradigm to aid decision making in stroke care. *Am Heart J* 2015;170(1):36-45, 45.e1-11. doi: 10.1016/j.ahj.2015.04.008 [published Online First: 2015/06/22]
21. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370(9596):1453-7. doi: 10.1016/S0140-6736(07)61602-X
22. Myles PS, Leslie K, Chan MT, et al. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial. *Lancet* 2014;384(9952):1446-54. doi: 10.1016/s0140-6736(14)60893-x [published Online First: 2014/08/22]
23. Myles PS, Smith JA, Forbes A, et al. Stopping vs. Continuing Aspirin before Coronary Artery Surgery. *N Engl J Med* 2016;374(8):728-37. doi: 10.1056/NEJMoa1507688
24. Myles PS, Smith JA, Forbes A, et al. Tranexamic acid in coronary artery surgery. *N Engl J Med* 2016;2016(in press)
25. Thompson EG, Gower ST, Beilby DS, et al. Enhanced recovery after surgery program for elective abdominal surgery at three Victorian hospitals. *Anaesth Intensive Care* 2012;40(3):450-9. [published Online First: 2012/05/15]
26. Christelis N, Wallace S, Sage CE, et al. An enhanced recovery after surgery program for hip and knee arthroplasty. *Med J Aust* 2015;202(7):363-8.
27. Glassford NJ, Myles P, Bellomo R. The Australian approach to peri-operative fluid balance. *Curr Opin Anaesthesiol* 2012;25(1):102-10. doi: 10.1097/ACO.0b013e32834decd7 [published Online First: 2011/11/25]
28. Vijay A, Grover A, Coulson T, et al. Perioperative management of patients treated with angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers. *Anaesth Intensive Care* 2016;in press
29. Shulman MA, Myles PS, Chan MT, et al. Measurement of disability-free survival after surgery. *Anesthesiology* 2015;122(3):524-36. doi: 10.1097/ALN.0000000000000586
30. Mangram A, Horan T, Pearson M, et al. Guideline for prevention of surgical site infection, 1999. *Infection Control and Hospital Epidemiology* 1999;20:247-77.
31. Degnim AC, Throckmorton AD, Boostrom SY, et al. Surgical site infection after breast surgery: impact of 2010 CDC reporting guidelines. *Ann Surg Oncol* 2012;19(13):4099-103. doi: 10.1245/s10434-012-2448-6
32. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Circulation* 2012;126(16):2020-35. doi: 10.1161/CIR.0b013e31826e1058

CIR.0b013e31826e1058 [pii] [published Online First: 2012/08/28]
33. Leonardi S, Armstrong PW, Schulte PJ, et al. Implementation of standardized assessment and reporting of myocardial infarction in contemporary randomized controlled trials: a systematic review. *Eur Heart J* 2013;34(12):894-902d. doi: 10.1093/eurheartj/eht003

eht003 [pii] [published Online First: 2013/01/29]
34. WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. Available from www.wma.net/en/30publications/10policies/b3/index.html (accessed 17 October 2012).

35. Caironi P, Tognoni G, Masson S, Fumagalli R, Persenti A, Romero M, et al. Albumin replacement in patients with severe sepsis or septic shock. N Engl J Med. 2014. doi: 10.1056/NEJMoa1305727.
36. Koenker R, Bassett G. Regression quantiles. *Econometrica* 1978;46:33–50.
37. Koenker R, Machado JAF. Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association* 1999;94:1296–310.
38. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. *Health Aff (Millwood)* 2008;27(3):759-69. doi: 10.1377/hlthaff.27.3.759
39. Lee VS, Kawamoto K, Hess R, et al. Implementation of a Value-Driven Outcomes Program to Identify High Variability in Clinical Costs and Outcomes and Association With Reduced Cost and Improved Quality. *Jama* 2016;316(10):1061-72. doi: 10.1001/jama.2016.12226 [published Online First: 2016/09/14]
40. Bauer M, Fitzgerald L, Haesler E, et al. Hospital discharge planning for frail older people and their family. Are we delivering best practice? A review of the evidence. *J Clin Nurs* 2009;18(18):2539-46. doi: 10.1111/j.1365-2702.2008.02685.x [published Online First: 2009/04/21]
41. Birkmeyer JD, Gust C, Dimick JB, et al. Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg* 2012;255(1):1-5. doi: 10.1097/SLA.0b013e3182402c17
42. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009;360(14):1418-28. doi: 10.1056/NEJMsa0803563 [published Online First: 2009/04/03]
43. Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, Observation, and the Hospital Readmissions Reduction Program. *N Engl J Med* 2016;374(16):1543-51. doi: 10.1056/NEJMsa1513024
44. Danino JF, Taylor T, Metcalfe CW, et al. Readmission rates and financial penalties after ear, nose and throat surgery: how can we improve? *Br J Hosp Med (Lond)* 2015;76(11):655-7. doi: 10.12968/hmed.2015.76.11.655
45. Hannan EL, Zhong Y, Lahey SJ, et al. 30-Day Readmissions After Coronary Artery Bypass Graft Surgery in New York State. *JACC: Cardiovascular Interventions* 2011;4(5):569-76. doi: http://dx.doi.org/10.1016/j.jcin.2011.01.010
46. Ahmed J, Khan S, Lim M, et al. Enhanced recovery after surgery protocols - compliance and variations in practice during routine colorectal surgery. *Colorectal Dis* 2012;14(9):1045-51. doi: 10.1111/j.1463-1318.2011.02856.x [published Online First: 2011/10/12]
47. Group EC. The Impact of Enhanced Recovery Protocol Compliance on Elective Colorectal Cancer Resection: Results From an International Registry. *Ann Surg* 2015;261(6):1153-9. doi: 10.1097/SLA.0000000000001029
48. Myles PS, Devereaux PJ. Pros and cons of composite endpoints in anesthesia trials. *Anesthesiology* 2010;113(4):776-8. doi: 10.1097/ALN.0b013e3181ee2ceb [published Online First: 2010/09/03]
49. Ferreira-Gonzalez I, Permanyer-Miralda G, Busse JW, et al. Composite outcomes can distort the nature and magnitude of treatment benefits in clinical trials. *Ann Intern Med* 2009;150(8):566-7. doi: 150/8/566-b [pii] [published Online First: 2009/04/22]
50. Pogue J, Thabane L, Devereaux PJ, et al. Testing for heterogeneity among the components of a binary composite outcome in a clinical trial. *BMC Med Res Methodol* 2010;10:49. doi: 10.1186/1471-2288-10-49
51. Khuri SF, Henderson WG, DePalma RG, et al. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242(3):326-41; discussion 41-3. doi: 00000658-200509000-00004 [pii] [published Online First: 2005/09/02]

52. Myles PS, Peyton P, Silbert B, et al. Perioperative epidural analgesia for major abdominal surgery for cancer and recurrence-free survival: randomised trial. *BMJ* 2011;342:d1491. doi: 10.1136/bmj.d1491

bmj.d1491 [pii] [published Online First: 2011/03/31]

53. Sheingold SH, Zuckerman R, Shartzer A. Understanding Medicare Hospital Readmission Rates And Differing Penalties Between Safety-Net And Other Hospitals. *Health Aff (Millwood)* 2016;35(1):124-31. doi: 10.1377/hlthaff.2015.0534

Table 1. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Types of Surgery.

Surgery	No. of patients	No. admitted to a rehabilitation hospital (%)	Median (95% CI) DAH_{30}†
Cardiac	679	54 (8.0)	22.8 (22.6-22.9)
Orthopaedic	289	122 (42)	21.9 (21.2-22.6)
Neurosurgery	220	9 (4.0)	22.8 (22.2-23.5)
Colorectal	118	8 (6.8)	24.9 (23.9-26.0)
Urology	315	26 (8.3)	23.8 (23.0-24.5)
Vascular	56	1 (1.8)	26.0 (24.3-27.3)
Ear, nose, throat	99	17 (17)	25.8 (24.9-27.0)
Oesophagogastric/hepatobiliary	253	4 (1.6)	24.9 (23.8-26.1)
Thoracic	28	2 (7.1)	22.8 (17.8-27.8)
Other	52	2 (3.8)	28.8 (27.7-30.0)

† hospital days do not include those spent in a rehabilitation facility

Table 2. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw median DAH_{30} (95% CI)	P value	Adjusted median DAH_{30} (95% CI)†	P-value
Patient age			<0.001		<0.001
<50 years	220 (11)	24.9 (24.4 - 25.4)		24.8 (24.4 - 25.2)	
50-60 years	396 (19)	24.0 (23.4 - 24.6)		24.4 (24.0 - 24.9)	
60-70 years	612 (29)	23.9 (23.8 - 24.0)		24.0 (23.6 - 24.3)	
70-80 years	653 (31)	22.8 (22.6 - 23.0)		23.0 (22.7 - 23.4)	
≥80 years	228 (11)	22.7 (22.0 - 23.5)		22.2 (21.7 - 22.7)	
Sex			0.042		0.14
Male	1427 (68)	23.7 (23.1 - 24.2)		23.7 (23.5 - 24.0)	
Female	682 (32)	24.0 (23.7 - 24.2)		23.5 (23.2 - 23.8)	
Smoker			0.094		
yes	787 (37)	23.2 (22.6 - 23.8)		not done	
no	1322 (63)	23.8 (23.7 - 23.9)		not done	
Diabetes			0.003		
yes	697 (33)	23.0 (22.4 - 23.6)		not done	
no	1412 (67)	23.8 (23.8 - 23. 9)		not done	
Heart failure					
yes	365 (17)	22.9 (22.4 - 23.4)	0.002	not done	
no	1744 (83)	23.8 (23.7 - 23.9)		not done	
ASA physical status					<0.001
1	41 (1.9)	28.0 (26.3 - 29.7)	<0.001	25.9 (25.1 - 26.6)	
2	530 (25)	25.0 (24.7 - 25.3)		24.4 (24.0 - 24.7)	
3	1024 (51)	23.7 (23.1 - 24.3)		23.6 (23.2 - 23.9)	
4	510 (24)	22.0 (21.4 - 22.5)		23.0 (22.6 - 23.3)	
Duration of Surgery, h			<0.001		<0.001
<2.0	581 (29)	25.9 (25.7 - 26.1)		25.6 (25.2 - 26.0)	
2.0-2.99	412 (20)	24.0 (23.5 - 24.5)		24.0 (23.7 - 24.3)	
3.0-3.99	551 (26)	22.9 (22.8 - 23.1)		23.1 (22.7 - 23.4)	
≥4.0	565 (27)	21.9 (21.4 - 22.3)		22.0 (21.6 - 22.5)	

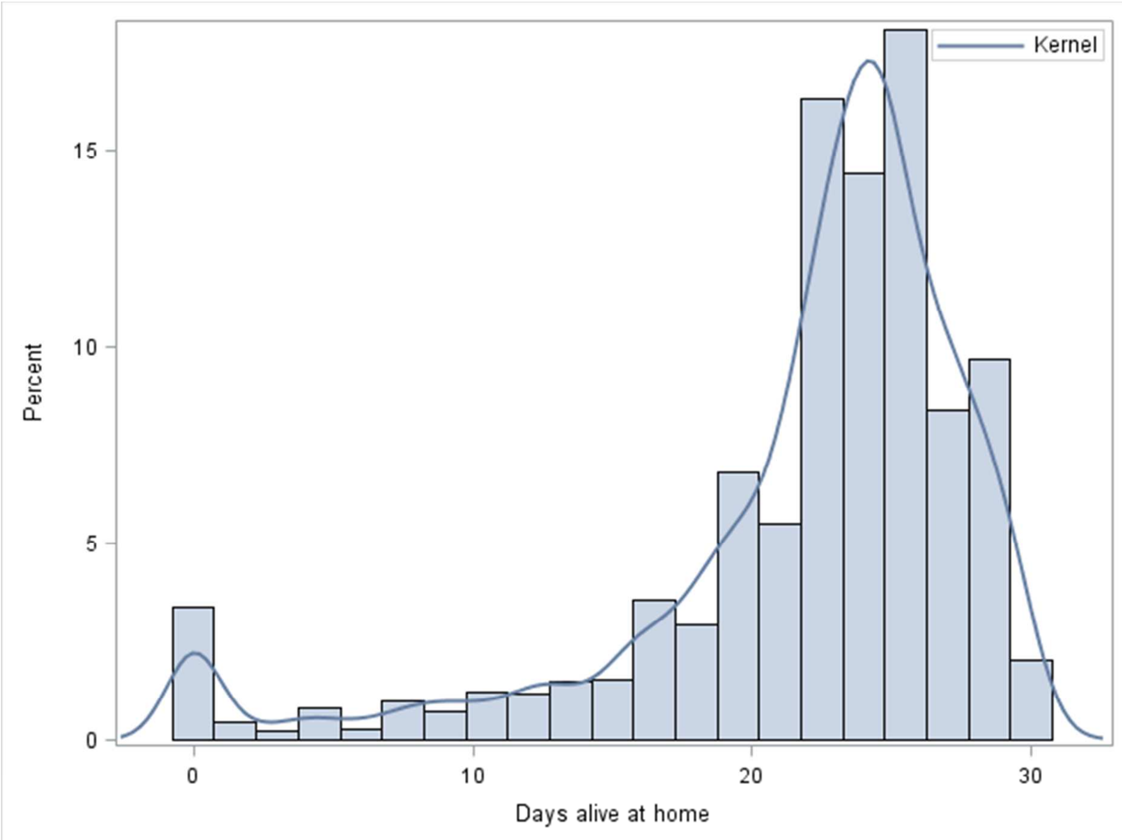
†covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table 3. Median (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value†
Myocardial infarction (120 [6.5])	1846	20.8 (19.2 - 22.4)	23.8 (23.7 - 23.9)	<0.001
Stroke (13 [0.7])	1846	10.1 (2.5 - 17.7)	23.8 (23.5 - 24.0)	<0.001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.4 - 25.9)	23.7 (23.5 - 24.0)	0.012
Cardiac arrest (3 [0.2])	1846	17.7 (0.9 - 34.5)	23.7 (23.5 - 24.0)	0.018
Surgical site infection (129 [7.0])	1846	21.0 (19.0 - 23.0)	23.8 (23.7 - 23.9)	<0.001
Any of the above (263 [14.2])	1846	20.5 (19.1 - 21.9)	23.9 (23.8 - 23.9)	<0.001
Hospital readmission (150 [7.1])	2090	17.9 (16.3 - 19.5)	23.9 (23.8 - 23.9)	<0.001

† P values calculated using likelihood ratio test.

Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.



Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Days Alive and at Home after Surgery

Table S1. Trial Data Sources

Trial	N	Reference
1. Tranexamic acid in coronary artery surgery	613	N Engl J Med 2016; Oct
2. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial	516	Lancet 2014; 384:1446-54.
3. An enhanced recovery after surgery (ERAS) program for hip and knee arthroplasty	310	Med J Aust 2015; 202:363-8.
4. Experience of an enhanced recovery after surgery (ERAS) program for elective abdominal surgery	71	Anaesth Intensive Care 2012; 40:450-9.
5. The measurement of disability-free survival after surgery	163	Anesthesiology 2015; 122:524-36.
6. Perioperative management of patients treated with angiotensin converting enzyme inhibitors and angiotensin II receptor blockers: a quality improvement audit	263	Anaesth Intensive Care 2016; 44:346-52.
7. Restrictive versus liberal fluid therapy in major abdominal surgery	173	ClinicalTrials.gov NCT01424150

Table S2. Third Quartile (Q3) Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw Q3 DAH_{30} (95% CI)	P value	Adjusted Q3 DAH_{30} (95% CI)*	P-value
Patient age					
<50 years	220 (11)	27.2 (26.5 , 27.9)	<.0001	26.1 (25.8 , 26.5)	<0.0001
50-60 years	396 (19)	25.9 (25.5 , 26.4)		26.1 (25.9 , 26.4)	
60-70 years	612 (29)	25.7 (25.0 , 26.4)		25.8 (25.6 , 26.1)	
70-80 years	653 (31)	25.0 (24.6 , 25.4)		25.1 (24.8 , 25.4)	
≥80 years	228 (11)	24.8 (24.3 , 25.3)		24.7 (24.1 , 25.4)	
Sex					
Male	1427 (68)	25.1 (24.8 , 25.4)	<.0001	25.6 (25.5 , 25.8)	0.146
Female	682 (32)	26.2 (25.6 , 26.8)		25.4 (25.2 , 25.7)	
Smoker					
yes	787 (37)	25.0 (24.8 , 25.1)	<.0001	not done	
no	1322 (63)	26.0 (25.7 , 26.2)		not done	
Diabetes					
yes	697 (33)	25.8 (25.1 , 26.5)	>.99	not done	
no	1412 (67)	25.8 (25.6 , 26.0)		not done	
Heart failure					
yes	365 (17)	25.9 (25.2 , 26.7)	0.39	not done	
no	1744 (83)	25.8 (25.4 , 26.2)		not done	
ASA physical status					
1	41 (1.9)	29.0 (28.8 , 29.3)	<.0001	26.6 (26.0 , 27.2)	<0.0001
2	530 (25)	27.0 (26.9 , 27.1)		26.3 (26.0 , 26.6)	
3	1024 (51)	25.8 (25.3 , 26.3)		25.5 (25.3 , 25.8)	
4	510 (24)	23.9 (23.8 , 24.0)		24.8 (24.5 , 25.1)	
Duration of Surgery, h					
<2.0	581 (29)	28.1 (27.7 , 28.6)	<.0001	27.6 (27.3 , 28.0)	<0.0001
2.0-2.99	412 (20)	26.1 (25.6 , 26.5)		25.8 (25.4 , 26.2)	
3.0-3.99	551 (26)	24.8 (24.7 , 24.9)		24.8 (24.5 , 25.0)	
≥4.0	565 (27)	23.9 (23.8 , 23.9)		24.1 (23.8 , 24.4)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table S3. Third Quartile (Q3) (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	22.9 (22.2 - 23.5)	25.8 (25.4 - 26.2)	<0.0001
Stroke (13 [0.7])	1846	18.9 (10.0 - 27.8)	25.2 (24.6 - 25.7)	0.019
Pulmonary embolism (7 [0.4])	1846	23.1 (16.1 - 30.1)	25.2 (24.6 - 25.7)	0.19
Cardiac arrest (3 [0.2])	1846	20.1 (8.0 - 32.1)	25.2 (24.6 - 25.7)	0.052
Surgical site infection (129 [7.0])	1846	24.8 (23.7 - 26.0)	25.3 (24.7 - 25.9)	<0.0001
Any of the above (263 [14.2])	1846	23.7 (23.0 - 24.5)	25.8 (25.6 - 26.1)	<0.0001
Hospital readmission (150 [7.1])	2090	21.7 (20.8 - 22.7)	25.9 (25.8 - 26.0)	<0.0001

[a] P values calculated using likelihood ratio test.

Table S4. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.

Surgery	No. admitted to a rehabilitation hospital (%)	Mean (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.7-22.9)
Orthopaedic (n=289)	122 (42)	21.9 (21.2-22.6)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (24.1-25.8)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.9-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

Table S5. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value
Patient age			<.0001		<0.0001
<50 years	220 (11)	24.9 (24.5 - 25.2)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.5 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.2 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.4 (20.4 - 22.4)	
Sex			0.90		0.0052
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.4 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			>0.99		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.6 - 23.4)			
Diabetes			.091		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.6 - 23.8)			
Heart failure			.16		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status					
1	41 (1.9)	27.9 (26.1 - 29.7)		25.3 (24.3 - 26.3)	<0.0001
2	530 (25)	24.9 (24.6 - 25.1)	<.0001	24.0 (23.6 - 24.5)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.3)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.3)		23.6 (23.2 - 24.0)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table S6. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.6 - 21.5)	23.1 (22.6 - 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.7 - 16.5)	23.0 (22.8 - 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.0 - 26.3)	23.0 (22.7 - 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.7 - 29.4)	23.0 (22.8 - 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (18.9 - 22.6)	23.1 (22.6 - 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 - 20.8)	23.7 (23.3 - 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 - 19.0)	23.7 (23.3 - 24.1)[b]	<0.0001

[a] P values calculated using the Likelihood ratio test.
[b] days calculated for those without readmission after excluding postoperative deaths.

BMJ Open

Legend

Validation of Days at Home as an Outcome Measure after Surgery: analysis of clinical trial data

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-015828.R1
Article Type:	Research
Date Submitted by the Author:	27-Apr-2017
Complete List of Authors:	Myles, Paul; Alfred Hospital and Monash University, Anaesthesia and Perioperative Medicine Shulman, Mark; Alfred Hospital Heritier, Stephane; School of Public Health and Preventive Medicine, Monash University, Department of Epidemiology and Preventive Medicine Wallace, Sophie; Alfred Hospital McIlroy, David; Alfred Hospital, Department of Anaesthesia and Perioperative Medicine McCluskey, Stuart; University Health Network, Anesthesia and Pain Medicine Sillar, Isabella; Alfred Hospital Forbes, Andrew; Monash University
Primary Subject Heading:	Anaesthesia
Secondary Subject Heading:	Surgery, Epidemiology
Keywords:	STATISTICS & RESEARCH METHODS, outcome, perioperative medicine, Clinical trials < THERAPEUTICS

Validation of Days at Home as an Outcome Measure after Surgery: analysis of clinical trial data

Paul S. Myles,[1,2,3] Mark A. Shulman,[1] Stephane Heritier,[3] Sophie Wallace,[1] David R. McIlroy,[1,2] Stuart McCluskey,[4] Isabella Sillar,[2] Andrew Forbes[3]

[1]Department of Anaesthesia and Perioperative Medicine, Alfred Hospital, Melbourne, Australia
[2]Department of Anaesthesia and Perioperative Medicine, Monash University, Melbourne, Australia
[3]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia
[4]Toronto General Hospital and University of Toronto, Toronto, ON, Canada

ADDRESS FOR CORRESPONDENCE
Paul S. Myles
Professor and Chair
Department of Anaesthesia and Perioperative Medicine
Alfred Hospital, Commercial Road, Melbourne, Victoria, 3004, Australia

Email: p.myles@alfred.org.au

Word count: 3050

Competing interest statement - All authors declare that the answer to the questions on the competing interest form are all No and therefore have nothing to declare.

Funding - The Australian and New Zealand College of Anaesthetists; and the Australian National Health and Medical Research Council Practitioner Fellowship (Prof Myles).

ABSTRACT

OBJECTIVE To evaluate "days at home up to 30 days after surgery" (DAH_{30}) as a patient-centred outcome measure.

DESIGN Prospective cohort study.

DATA SOURCE Using clinical trial data (7 trials, 2109 patients) we calculated DAH_{30} from length of stay, re-admission, discharge destination, and death up to 30 days after surgery.

MAIN OUTCOME The association between DAH_{30} and serious complications after surgery.

RESULTS One or more complications occurred in 263 of 1846 (14.2%) patients, including 19 (1.0%) deaths within 30 days of surgery; 245 (11.6%) patients were discharged to a rehabilitation facility and 150 (7.1%) were readmitted to hospital within 30 days of surgery. The median DAH_{30} was significantly less in older patients (P<0.001), those with poorer physical functioning (P<0.001), and in those undergoing longer operations (P<0.001). Patients with serious complications had less days at home than patients without serious complications (20.5 [95% CI, 19.1 to 21.9] vs 23.9 [95% CI, 23.8 to 23.9] P<0 .001), and had higher rates of readmission (16.0% vs. 5.9%; P < 0.001). After adjusting for patient age, sex, physical status and duration of surgery, the occurrence of postoperative complications was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.001).

CONCLUSIONS DAH_{30} has construct validity and is a readily-obtainable generic patient-centred outcome measure. It is a pragmatic outcome measure for perioperative clinical trials.

Strengths and limitations of the study

- This study integrates length of stay, re-admission, discharge destination, and early deaths after surgery into a single outcome metric, “days at home up to 30 days after surgery” (DAH_{30})
- DAH_{30} is an ideal, patient-centred outcome measure for perioperative clinical trials and quality assurance activities
- Accurate calculation of DAH_{30} requires knowledge of post-discharge location (home or nursing facility) and any re-admissions at the index or other hospitals
- Because early deaths heavily influence the DAH_{30} metric, this information should be additionally reported if, say, the incidence exceeds 10%

Introduction

Surgery and other interventional procedures are intended to relieve symptoms and in many cases prolong life. But surgery is not risk-free; perioperative complications can impair patient recovery resulting in prolonged hospitalization, short or longer term disability, and sometimes poor survival. A wide variety of outcome measures have been used to quantify each of these aspects of the postoperative experience but few provide a broad, patient-centred perspective of effective and efficient care;[1] these are needed to better inform the current shift towards value-based healthcare.[2 3]

Patient-centred care requires clinicians to consider outcomes that matter most to patients. That is, the patient's experience of their illness, quality of life, and functioning; their values, preferences and goals for health care.[4] Loss of the ability to live independently is a major concern for the elderly;[5 6] it is clearly a patient-centred outcome, and has been associated with postoperative readmissions and death after hospital discharge.[5]

Specific peri-procedural complications such as surgical site infection, respiratory failure, delirium, and myocardial infarction are clearly important to patients and physicians alike, but reliable and consistent detection is problematic. In any case such information is an incomplete description of the overall success of surgery and other perioperative care, and does not describe the impact of such complications on functioning and need for institutionalization. Similar challenges occur when nominating endpoints in clinical trials, including a lack of standardisation,[7] need for adjudication, and uncertainty about the overall health impact of each endpoint on a patient's recovery. There is a growing acceptance that

outcome measures used in clinical trials should be determined in partnership by patients and physician-researchers, aiming to identify outcomes that are important to patients.[8]

"Days alive and out of hospital" has been shown to be a readily quantifiable and patient-centred outcome measure in some chronic cardiovascular conditions such as heart failure and atrial fibrillation,[9-11] and in geriatric medicine,[12] but it has not been used as an outcome measure in perioperative trials. Home discharge has been proposed as a proxy for a patient's recovery after surgery,[13] and is estimated when using the American College of Surgeons' Surgical Risk Calculator,[14] but this does not account for readmissions or early deaths, although the latter collects and reports some of this information.[15]

Our own work and that of others have shown that early return home after surgery,[6 16-18] and medical illnesses such as stroke,[19 20] is highly valued by patients but could be undermined if the patient were to be transferred to another type of nursing facility. A more favourable perioperative outcome measure should account for both the initial hospital stay associated with the index surgery, rehospitalisation due to post-discharge complications, discharge to institutional care, and early deaths.

We thus chose to evaluate the utility of "days (alive and) at home" within 30 days of surgery (DAH_{30}) in the surgical/perioperative setting as a patient-centred outcome measure for perioperative clinical trials and quality improvement activities. Our hypothesis was that DAH_{30} would be lower in higher risk patients, those undergoing more extensive surgery, and in those with complications after surgery (i.e. it has construct validity).

Methods

This manuscript was written in adherence to the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement.[21]

Study Design and Data Sources

Data were obtained from each of seven recently completed clinical trials that prospectively enrolled patients undergoing various types of elective and emergency surgery at the Alfred Hospital in Melbourne, Australia. The cohort consisted of four multicentre randomised trials and three before-and-after studies (see Table S1 in the Supplementary Appendix).[22-29] For each trial we collected a comparable set of patient demographic and perioperative characteristics, and clinical outcome measures, including complete hospital discharge, discharge destination (home, rehabilitation facility, nursing home) and re-admission data. All but one study[28] prospectively recorded re-admission data; for the latter study we could obtain this information retrospectively from our hospital information system. Both the present study and each of the original trials received institutional ethics committee approval.

Patients

Patients 18 years and older undergoing an elective or non-elective inpatient operation enrolled in one of the aforementioned trials were included. Study inclusion criteria were established for the original studies and typically identified those at increased risk of postoperative complications. In all cases patients provided informed consent before enrolment in the original trials.

Patient involvement

Hospital patients have previously indicated the importance of returning home after hospitalisation for medical or surgical conditions, [6 16-20] but we did not involve patients or their carers in the design or conduct of this study.

Risk Factors and Outcomes

Perioperative data included patient demographics, comorbidity, functional status, type and duration of surgery, hospital length of stay, hospital readmission(s), and in all but one study[28] we prospectively collected selected complications at 30 days after surgery: wound infection, myocardial infarction, stroke, pulmonary embolism, cardiac arrest, and death.

Hospital discharge data were used to calculate hospital length of stay. Whether the patient was discharged from hospital to their home or to a nursing facility was obtained from the electronic medical record, but for those admitted to a rehabilitation facility we were unable to ascertain the number of days admitted before eventual discharge home. For those readmitted to hospital we combined the original length of stay with subsequent hospital stay(s) to calculate total length of stay within 30 days postoperatively.

DAH_{30} was calculated using mortality and hospitalisation data from the date of the index surgery (Day 0). For example, if a patient died on day 2 after their surgery, they were assigned 0 DAH_{30}, if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they were assigned 20 DAH_{30}. If a patient died within 30 days of surgery, irrespective of whether they

had spent some time at home, DAH_{30} was scored as zero (0). Further explanation is provided in the Supplementary Appendix.

Patients are commonly admitted to a post-acute hospital rehabilitation centre after lower limb arthroplasty and cardiac surgery in our setting; some frail and elderly patients are also transferred for ongoing convalescence. We were unable to reliably collect secondary length of stay for rehabilitation facilities - we thus did two secondary analysis, assuming the length of stay in a rehabilitation facility was 5 or 14 extra days. That is, $DAH_{30\text{-rehab5}}$ was calculated as DAH_{30}-5, and $DAH_{30\text{-rehab14}}$ was calculated as DAH_{30}-14, in secondary analyses.

For the multicentre trials,[22-24] a 12-lead electrocardiograph was recorded preoperatively and on day 1 and 3 after surgery. Blood for troponin (or if unavailable, creatine kinase-myocardial band) measurement was collected at 6 to 12 hours after surgery and on the first three postoperative days. In all trials laboratory tests were otherwise ordered if clinically indicated. Each complication was defined within the original study protocol and in all cases a consistent definition was used. In brief, surgical site infection was confirmed if associated with purulent discharge, with or without a positive microbial culture; or pathogenic organisms isolated from aseptically obtained microbial culture,[30] although the most recent trial[27] included documentation of a physician's diagnosis in this definition.[31] Pneumonia was confirmed by a new pulmonary infiltrate reported by chest x-ray or computerized tomography, in association with at least one of: temperature >38°C, white cell count >12,000/ml, or positive sputum culture that was not heavily contaminated with oral flora or that corresponded with positive blood cultures. Myocardial infarction was defined according to the third universal definition,[32] requiring elevated cardiac biomarker plus at least one of the

following: (i) ischaemic symptoms, (ii) pathological Q waves, (iii) electrocardiographic changes indicative of ischemia, (iv) coronary artery intervention or (v) new wall motion abnormality on echocardiography or scanning; or autopsy finding of myocardial infarction. The threshold for significant elevated troponin was the hospital laboratory's 99th percentile of a normal reference population (upper reference limit), according to recent recommendations.[33] Stroke was confirmed if a new neurological deficit persisting for at least 24 hours, verified by neurologist assessment and/or computerized tomography or magnetic resonance imaging.

Statistical Analysis[34 35]

Data were first merged and checked for inconsistencies. Patient age was grouped into 10-year categories, and hourly cut-points for duration of surgery (2, 3, and 4 h) were created to generate approximately similar group sizes and facilitate clinical interpretation. DAH_{30} was analysed using quantile regression.[36] This approach, well known in econometrics where it was initially introduced, allows the modelling of any quantile of a continuous endpoint, here DAH_{30}, as a linear combination of the covariates. As DAH_{30} is left skewed with a spike at zero, it is more relevant to model the median (or alternatively, the 75th percentile) that is closer to the major distribution mode and directly interpretable. The choice of the quantile(s) to be analysed can be prespecified or a range of values selected for their meaningfulness or exploratory purposes. Here the range 50th-75th percentile was deemed relevant. No assumption on the true distribution of the endpoint is required. The asymptotic distribution of the parameter estimates can be derived but depends on some unknown density estimate. In general, resampling methods are recommended to obtain confidence intervals (CIs).[37 38] Raw and adjusted medians and their 95% CIs obtained by bootstrapping as implemented in Stata with 1000 replicates were reported for key predictors. The adjusted models included age by 10-year categories, sex, American Society of Anesthesiologists (ASA) physical status score, surgery time (< 2h, 2.0 - 2.99, 3.0 -3.99, ≥4.0). A goodness of fit test[39] comparing this model to the full model including the same predictors plus smoking, heart failure and diabetes was not any better (P=0.36). A global test of effect of any key predictor was carried out using a quasi-likelihood ratio test.[39] Quantile regression was also used to test median differences between those with and without complications, and by postoperative complications. Supplementary analyses were done for the 75th percentile (Q3). All analyses were done using Stata 14.0 except the quasi-likelihood ratio test analysis that is only available in SAS. All tests were two-sided and performed at level ?=0.05; no correction was made for multiple comparisons.

Results

A total of 2109 eligible patients 18 years and older were enrolled into clinical trials and underwent inpatient operations at the Alfred Hospital between March 2006 and September 2016. The number of patients enrolled in each of the trials is detailed in the Supplement (Supplementary Table 1). The cohort included 1427 male patients (67.7%) with a mean (SD) age of 65 (12) years who underwent a range of inpatient operations (Table 1). Most operations were cardiac surgical procedures (679 [32.2%]), followed by general (489 [23.2%]), urologic (315 [14.9%]), and neurosurgical procedures (220 [10.4%]).

There was a bimodal, skewed distribution of DAH_{30} (Figure 1). The spike at zero consisted of 19 patients (1.0%) that died, and 40 patients remaining in hospital at least 30 days after

surgery. DAH_{30} and rates of admission to a rehabilitation centre varied according to type of surgery (Table 2).

One or more complications occurred in 263 (14.2%) patients. Overall, 245 (11.6%) patients were admitted to a rehabilitation facility and 150 (7.1%) were readmitted within 30 days of surgery. The median DAH_{30} was 23.7 (95% CI, 23.5 to 24.0), but this varied according to type of surgery (Table 1).

The median DAH_{30} was significantly less in older patients, current smokers, diabetics, those with poorer physical functioning, and undergoing longer operations (Table 2). These associations remained after adjustment for all of these covariates and patient sex (Table 2). The individual complications of myocardial infarction, stroke, pulmonary embolism, and surgical site infection were each associated with shorter DAH_{30} (Table 3) in a raw analysis. Hospital readmission was also a factor, decreasing median DAH_{30} when compared with those not readmitted to hospital, 17.9 (95% CI, 16.3 to 19.5) vs 23.9 (95% CI, 23.8 to 23.9), respectively (P<0.0001).

After adjusting for patient age, sex, ASA physical status and duration of surgery, the occurrence of any postoperative complication was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.0001).

Supplementary Analyses

The above findings were consistent when analysing the 3rd quartile distributions and differences (Tables S2-S4 in the Supplementary Appendix), and after accounting for the additional loss of days at home because of admission to a rehabilitation centre (Tables S5 – S9 in the Supplementary Appendix).

Discussion

We found that DAH_{30} has construct validity and is a readily-obtainable patient-centred outcome measure that could be used to better inform patients and physicians when planning surgery. Unlike previous related measures, DAH_{30} accounts for each of delayed hospital discharge because of postoperative complications, discharge to a rehabilitation centre or other post-acute care nursing facility, rehospitalisations, and postoperative deaths. It thus captures much of the surgical experience, integrating efficacy, quality and safety, and thus reflecting value-based care. It can also be risk-adjusted for bench-marking purposes. DAH_{30} will be maximized when patients recover free of complications after surgery, with optimal comfort and functioning - aligning with patient values and preferences, and goals for health care.[4]

Although concerns are frequently raised about the usefulness of hospital length of stay as an outcome measure after surgery, largely because of social factors and reluctance to discharge on weekends, it mostly adds variance (background noise) in clinical trials and is not biased. Very few hospitals have the luxury of extending a patient's stay in hospital for non-clinical reasons. Hospital stay is a reasonable surrogate for quality and speed of recovery after surgery, and it has marked resource/cost implications. Most patients want to go home as soon as possible – it is a desired outcome in and of itself.

The US has a triple aim of improving the healthcare system: improving the patient experience of care, improving the health of populations, and reducing per capita costs of healthcare.[40] DAH_{30} seems to be useful, generic metric in this regard.[41] DAH_{30} is a measure of the overall burden of care, both in hospital and post-discharge. The perceived success of a hospital discharge plan as perceived by the patient and their principal carer depends on clear communication and meeting expectations.[42] DAH_{30} offers transparency and opportunities for benchmarking performance, both of which are important components of quality improvement.[1 3] It may influence alternative payment contracts for hospitals.

Postoperative complications add to hospital costs and increase length of stay.[43] Higher episode payments at “lower-quality” hospitals have been attributed to higher rates of complications, 30-day readmissions, and post-discharge ancillary care.[43] Serious postoperative complications are both strongly associated with readmission,[5 17] increasing the risk by 6.7-fold, and loss of independence.[5] Readmission is a frequent, costly, and sometimes life-threatening event that is associated with gaps in follow-up care.[15 17 44] Readmission after surgery is thus an established quality indicator. Trends in readmissions suggest that US hospitals are responding to incentives to reduce readmissions under the Affordable Care Act.[45 46] Hospital readmission rates are not highly correlated with mortality rates, [47] so they offer an independent and more sensitive measure of quality. Even though some readmissions are due to chronic medical conditions,[44] optimal perioperative care should keep these to a minimum and such improvements should be reflected in more DAH_{30}.

Enhanced recovery after surgery programs are designed to reduce complications and shorten length of stay. But this sometimes comes at the cost of increased hospital re-admissions.[48 49] The measurement and reporting of DAH_{30} would identify this and hopefully encourage further quality improvement. Planned discharge to a rehabilitation facility sometimes forms part of an enhanced recovery pathway, and in any case may not be seen by the patient or their family as indicating a poor outcome. Therefore, calculation of DAH_{30} in some studies could incorporate days spent in a rehabilitation facility as equivalent to being home. In contrast, unplanned admission to a rehabilitation facility would indicate poor care or adverse outcome, and this should be retained in the calculation of DAH_{30}. Care should be taken to avoid missing out-of-network hospitalizations, particularly if relying on hospital system electronic medical records. The latter will otherwise enhance the efficiency of data collection.

Composite endpoints used in perioperative trials are often flawed,[50-52] typically used to increase the number of events in order to enhance statistical power. DAH_{30}, as a numerical patient-centred measure, provides more statistical power, can be reliably measured and has direct patient-centredness. Although some postoperative complications and poor survival can manifest many months after surgery in those recovering from major surgery or critical illness,[29 53 54] extending measurement out to 90 days after surgery (i.e. DAH_{90}) may not necessarily provide new or different information because the extra burden and costs of further data collection may outweigh the benefits of the extra information obtained. In addition, disease progression or other aspects of life may confound outcome evaluation of perioperative care.

Our study has several limitations. First, this was a single-centre study of clinical trial data collected for other purposes. Second, postoperative in-hospital deaths have a major influence on the calculation of DAH_{30}; this is arguably appropriate because perioperative studies should weight this as the most extreme adverse outcome. More sophisticated modelling could jointly model the risk of death and DAH_{30} in those discharged alive, and such modelling would be particularly important if the in-hospital mortality rate is moderate or greater. Third, different health care settings can be expected to have varied casemix and hospital discharge processes, and hospital discharge may be delayed because of social and process issues unrelated to complications or quality of care. DAH_{30} should therefore be risk-adjusted.[55] Fourth, DAH_{30} doesn't provide specific information on which aspects of in-hospital or post-discharge management influences where patients reside after hospitalization, or the post-discharge use and effectiveness of family physician or other health care resources. Fifth, DAH_{30} is an overall measure of recovery profile and does not inform us about specific complications, level of functioning or wellbeing. Such aspects should also be included when conducting outcome studies. Sixth, obtaining accurate data on days spent in a rehabilitation facility relies on further follow-up or accurate electronic records. Future studies using DAH_{30} should prospectively plan to reliably obtain such data.

CONCLUSIONS

DAH_{30} has construct validity and is a readily-obtainable, generic, patient-centred outcome measure that can better inform patients and physicians when planning surgery. It is a suitable outcome measure for both quality improvement and perioperative clinical trials. DAH_{30} accounts for prolonged hospital stay, discharge to any post-acute care nursing facility,

rehospitalizations, and early deaths. It thus captures much of the patient-centred experience, and will be maximal when effective and efficient care is achieved.

Contributor statement: PM designed the study, oversaw the ethics application, devised the statistical analysis plan, and drafted and revised the paper. He is guarantor. MS provided intellectual input into the study design, and drafted and revised the paper. SH analysed the data and drafted and revised the paper. SW prepared the ethics application, monitored the data entry and checking, and drafted and revised the paper. DM provided intellectual input into the study design, and drafted and revised the paper. SM provided intellectual input into the study design, and drafted and revised the paper. IS retrieved and entered all study data, and revised the paper. AF contributed to the statistical analysis, and drafted and revised the paper.

Transparency declaration: The lead author* affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Acknowledgment: The authors would like to thank the study participants for their interest and preparedness to consent to the original trials. PM is supported in part by Practitioner Fellowships from the Australian National Health and Medical Research Council (NHMRC).

Funding: This work was supported by the Australian NHMRC, the New Zealand Health Research Council, and the Australian and New Zealand College of Anaesthetists, and Monash University (Melbourne, Australia).

Additional data: No additional data available.

Competing interests: None of the authors have any conflicts of interest

Ethics approval: This trial has been approved by the Ethics Committees of Alfred Health, Melbourne, Australia.

References

1. Austin JM, McGlynn EA, Pronovost PJ. Fostering Transparency in Outcomes, Quality, Safety, and Costs. *Jama* 2016 doi: 10.1001/jama.2016.14039 [published Online First: 2016/09/27]
2. Lynn J, McKethan A, Jha AK. Value-Based Payments Require Valuing What Matters to Patients. *JAMA* 2015;314(14):1445-6. doi: 10.1001/jama.2015.8909
3. Porter ME. What is value in health care? *N Engl J Med* 2010;363(26):2477-81. doi: 10.1056/NEJMp1011024 [published Online First: 2010/12/15]
4. Lavallee DC, Chenok KE, Love RM, et al. Incorporating Patient-Reported Outcomes Into Health Care To Engage Patients And Enhance Care. *Health Aff (Millwood)* 2016;35(4):575-82. doi: 10.1377/hlthaff.2015.1362 [published Online First: 2016/04/06]
5. Berian JR, Mohanty S, Ko CY, et al. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg* 2016;151(9):e161689. doi: 10.1001/jamasurg.2016.1689 [published Online First: 2016/07/14]
6. Fried TR, Bradley EH, Towle VR, et al. Understanding the treatment preferences of seriously ill patients. *N Engl J Med* 2002;346(14):1061-6. doi: 10.1056/NEJMsa012528
7. Goldfarb M, Drudi L, Almohammadi M, et al. Outcome Reporting in Cardiac Surgery Trials: Systematic Review and Critical Appraisal. *J Am Heart Assoc* 2015;4(8):e002204. doi: 10.1161/jaha.115.002204 [published Online First: 2015/08/19]
8. Chalmers I, Clarke M. Outcomes that matter to patients in tombstone trials. *Lancet* 2001;358(9293):1649. doi: S0140673601066892 [pii] [published Online First: 2001/11/22]
9. Ariti CA, Cleland JG, Pocock SJ, et al. Days alive and out of hospital and the patient journey in patients with heart failure: Insights from the candesartan in heart failure: assessment of reduction in mortality and morbidity (CHARM) program. *Am Heart J* 2011;162(5):900-6. doi: 10.1016/j.ahj.2011.08.003
10. Wasywich CA, Gamble GD, Whalley GA, et al. Understanding changing patterns of survival and hospitalization for heart failure over two decades in New Zealand: utility of 'days alive and out of hospital' from epidemiological data. *Eur J Heart Fail* 2010;12(5):462-8. doi: 10.1093/eurjhf/hfq027
11. Xian Y, Wu J, O'Brien EC, et al. Real world effectiveness of warfarin among ischemic stroke patients with atrial fibrillation: observational analysis from Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research (PROSPER) study. *BMJ* 2015;351:h3786. doi: 10.1136/bmj.h3786
12. Ellis G, Whitehead MA, Robinson D, et al. Comprehensive geriatric assessment for older adults admitted to hospital: meta-analysis of randomised controlled trials. *Bmj* 2011;343:d6553. doi: 10.1136/bmj.d6553 [published Online First: 2011/10/29]
13. Hyder JA, Hirschberg RE, Nguyen LL. Home discharge as a performance metric for surgery. *JAMA Surg* 2015;150(2):96-7. doi: 10.1001/jamasurg.2014.1725 [published Online First: 2014/12/05]
14. Hyder JA, Wakeam E, Habermann EB, et al. Derivation and validation of a simple calculator to predict home discharge after surgery. *J Am Coll Surg* 2014;218(2):226-36. doi: 10.1016/j.jamcollsurg.2013.11.002
15. Merkow RP, Ju MH, Chung JW, et al. Underlying reasons associated with hospital readmission following surgery in the United States. *JAMA* 2015;313(5):483-95. doi: 10.1001/jama.2014.18614
16. Boney O, Bell M, Bell N, et al. Identifying research priorities in anaesthesia and perioperative care: final report of the joint National Institute of Academic Anaesthesia/James Lind Alliance Research Priority Setting Partnership. *BMJ Open* 2015;5(12):e010006. doi: 10.1136/bmjopen-2015-010006 [published Online First: 2015/12/18]
17. Hinami K, Bilimoria KY, Kallas PG, et al. Patient experiences after hospitalizations for elective surgery. *Am J Surg* 2014;207(6):855-62. doi: 10.1016/j.amjsurg.2013.04.014

18. Burns KE, Jacob SK, Aguirre V, et al. Stakeholder Engagement in Trial Design: Survey of Visitors to Critically Ill Patients Regarding Preferences for Outcomes and Treatment Options during Weaning from Mechanical Ventilation. *Ann Am Thorac Soc* 2016;13(11):1962-68. doi: 10.1513/AnnalsATS.201606-445OC [published Online First: 2016/09/07]
19. Hannah D, Lindholm B, Maisch L. Certain uncertainty: life after stroke from the patient's perspective. *Circ Cardiovasc Qual Outcomes* 2014;7(6):968-9. doi: 10.1161/CIRCOUTCOMES.114.001315
20. Xian Y, O'Brien EC, Fonarow GC, et al. Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research: Implementing the patient-driven research paradigm to aid decision making in stroke care. *Am Heart J* 2015;170(1):36-45, 45.e1-11. doi: 10.1016/j.ahj.2015.04.008 [published Online First: 2015/06/22]
21. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370(9596):1453-7. doi: 10.1016/S0140-6736(07)61602-X
22. Myles PS, Leslie K, Chan MT, et al. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial. *Lancet* 2014;384(9952):1446-54. doi: 10.1016/s0140-6736(14)60893-x [published Online First: 2014/08/22]
23. Myles PS, Smith JA, Forbes A, et al. Stopping vs. Continuing Aspirin before Coronary Artery Surgery. *N Engl J Med* 2016;374(8):728-37. doi: 10.1056/NEJMoa1507688
24. Myles PS, Smith JA, Forbes A, et al. Tranexamic acid in coronary artery surgery. *N Engl J Med* 2017;2017(376):136-48.
25. Thompson EG, Gower ST, Beilby DS, et al. Enhanced recovery after surgery program for elective abdominal surgery at three Victorian hospitals. *Anaesth Intensive Care* 2012;40(3):450-9. [published Online First: 2012/05/15]
26. Christelis N, Wallace S, Sage CE, et al. An enhanced recovery after surgery program for hip and knee arthroplasty. *Med J Aust* 2015;202(7):363-8.
27. Glassford NJ, Myles P, Bellomo R. The Australian approach to peri-operative fluid balance. *Curr Opin Anaesthesiol* 2012;25(1):102-10. doi: 10.1097/ACO.0b013e32834decd7 [published Online First: 2011/11/25]
28. Vijay A, Grover A, Coulson T, et al. Perioperative management of patients treated with angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers. *Anaesth Intensive Care* 2016;in press
29. Shulman MA, Myles PS, Chan MT, et al. Measurement of disability-free survival after surgery. *Anesthesiology* 2015;122(3):524-36. doi: 10.1097/ALN.0000000000000586
30. Mangram A, Horan T, Pearson M, et al. Guideline for prevention of surgical site infection, 1999. *Infection Control and Hospital Epidemiology* 1999;20:247-77.
31. Degnim AC, Throckmorton AD, Boostrom SY, et al. Surgical site infection after breast surgery: impact of 2010 CDC reporting guidelines. *Ann Surg Oncol* 2012;19(13):4099-103. doi: 10.1245/s10434-012-2448-6
32. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Circulation* 2012;126(16):2020-35. doi: 10.1161/CIR.0b013e31826e1058

CIR.0b013e31826e1058 [pii] [published Online First: 2012/08/28]
33. Leonardi S, Armstrong PW, Schulte PJ, et al. Implementation of standardized assessment and reporting of myocardial infarction in contemporary randomized controlled trials: a systematic review. *Eur Heart J* 2013;34(12):894-902d. doi: 10.1093/eurheartj/eht003

eht003 [pii] [published Online First: 2013/01/29]
34. WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. Available from www.wma.net/en/30publications/10policies/b3/index.html (accessed 17 October 2012).

35. Caironi P, Tognoni G, Masson S, Fumagalli R, Persenti A, Romero M, et al. Albumin replacement in patients with severe sepsis or septic shock. N Engl J Med. 2014. doi: 10.1056/NEJMoa1305727.
36. Koenker R, Bassett G. Regression quantiles. *Econometrica* 1978;46:33–50.
37. Wu CFJ. Jackknife, bootstrap and other resampling methods in regression analysis. *Ann Stat* 1986;14:1261-350.
38. He X, Hu F. Markov chain marginal bootstrap. *J Am Stat Assoc* 2002;97:783-95.
39. Koenker R, Machado JAF. Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association* 1999;94:1296–310.
40. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. *Health Aff (Millwood)* 2008;27(3):759-69. doi: 10.1377/hlthaff.27.3.759
41. Lee VS, Kawamoto K, Hess R, et al. Implementation of a Value-Driven Outcomes Program to Identify High Variability in Clinical Costs and Outcomes and Association With Reduced Cost and Improved Quality. *Jama* 2016;316(10):1061-72. doi: 10.1001/jama.2016.12226 [published Online First: 2016/09/14]
42. Bauer M, Fitzgerald L, Haesler E, et al. Hospital discharge planning for frail older people and their family. Are we delivering best practice? A review of the evidence. *J Clin Nurs* 2009;18(18):2539-46. doi: 10.1111/j.1365-2702.2008.02685.x [published Online First: 2009/04/21]
43. Birkmeyer JD, Gust C, Dimick JB, et al. Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg* 2012;255(1):1-5. doi: 10.1097/SLA.0b013e3182402c17
44. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009;360(14):1418-28. doi: 10.1056/NEJMsa0803563 [published Online First: 2009/04/03]
45. Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, Observation, and the Hospital Readmissions Reduction Program. *N Engl J Med* 2016;374(16):1543-51. doi: 10.1056/NEJMsa1513024
46. Danino JF, Taylor T, Metcalfe CW, et al. Readmission rates and financial penalties after ear, nose and throat surgery: how can we improve? *Br J Hosp Med (Lond)* 2015;76(11):655-7. doi: 10.12968/hmed.2015.76.11.655
47. Hannan EL, Zhong Y, Lahey SJ, et al. 30-Day Readmissions After Coronary Artery Bypass Graft Surgery in New York State. *JACC: Cardiovascular Interventions* 2011;4(5):569-76. doi: http://dx.doi.org/10.1016/j.jcin.2011.01.010
48. Ahmed J, Khan S, Lim M, et al. Enhanced recovery after surgery protocols - compliance and variations in practice during routine colorectal surgery. *Colorectal Dis* 2012;14(9):1045-51. doi: 10.1111/j.1463-1318.2011.02856.x [published Online First: 2011/10/12]
49. Group EC. The Impact of Enhanced Recovery Protocol Compliance on Elective Colorectal Cancer Resection: Results From an International Registry. *Ann Surg* 2015;261(6):1153-9. doi: 10.1097/SLA.0000000000001029
50. Myles PS, Devereaux PJ. Pros and cons of composite endpoints in anesthesia trials. *Anesthesiology* 2010;113(4):776-8. doi: 10.1097/ALN.0b013e3181ee2ceb [published Online First: 2010/09/03]
51. Ferreira-Gonzalez I, Permanyer-Miralda G, Busse JW, et al. Composite outcomes can distort the nature and magnitude of treatment benefits in clinical trials. *Ann Intern Med* 2009;150(8):566-7. doi: 150/8/566-b [pii] [published Online First: 2009/04/22]
52. Pogue J, Thabane L, Devereaux PJ, et al. Testing for heterogeneity among the components of a binary composite outcome in a clinical trial. *BMC Med Res Methodol* 2010;10:49. doi: 10.1186/1471-2288-10-49
53. Khuri SF, Henderson WG, DePalma RG, et al. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242(3):326-

41; discussion 41-3. doi: 00000658-200509000-00004 [pii] [published Online First: 2005/09/02]
54. Myles PS, Peyton P, Silbert B, et al. Perioperative epidural analgesia for major abdominal surgery for cancer and recurrence-free survival: randomised trial. *BMJ* 2011;342:d1491. doi: 10.1136/bmj.d1491

bmj.d1491 [pii] [published Online First: 2011/03/31]
55. Sheingold SH, Zuckerman R, Shartzer A. Understanding Medicare Hospital Readmission Rates And Differing Penalties Between Safety-Net And Other Hospitals. *Health Aff (Millwood)* 2016;35(1):124-31. doi: 10.1377/hlthaff.2015.0534

Legend

Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

Table 1. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Types of Surgery.

Surgery	No. of patients	No. admitted to a rehabilitation hospital (%)	Median (95% CI) DAH_{30}†
Cardiac	679	54 (8.0)	22.8 (22.6-22.9)
Orthopaedic	289	122 (42)	21.9 (21.2-22.6)
Neurosurgery	220	9 (4.0)	22.8 (22.2-23.5)
Colorectal	118	8 (6.8)	24.9 (23.9-26.0)
Urology	315	26 (8.3)	23.8 (23.0-24.5)
Vascular	56	1 (1.8)	26.0 (24.3-27.3)
Ear, nose, throat	99	17 (17)	25.8 (24.9-27.0)
Oesophagogastric/hepatobiliary	253	4 (1.6)	24.9 (23.8-26.1)
Thoracic	28	2 (7.1)	22.8 (17.8-27.8)
Other	52	2 (3.8)	28.8 (27.7-30.0)

† hospital days do not include those spent in a rehabilitation facility

Table 2. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw median DAH_{30} (95% CI)	P value	Adjusted median DAH_{30} (95% CI)†	P-value
Patient age			<0.001		<0.001
<50 years	220 (11)	24.9 (24.4 - 25.4)		24.8 (24.4 - 25.2)	
50-60 years	396 (19)	24.0 (23.4 - 24.6)		24.4 (24.0 - 24.9)	
60-70 years	612 (29)	23.9 (23.8 - 24.0)		24.0 (23.6 - 24.3)	
70-80 years	653 (31)	22.8 (22.6 - 23.0)		23.0 (22.7 - 23.4)	
≥80 years	228 (11)	22.7 (22.0 - 23.5)		22.2 (21.7 - 22.7)	
Sex			0.042		0.14
Male	1427 (68)	23.7 (23.1 - 24.2)		23.7 (23.5 - 24.0)	
Female	682 (32)	24.0 (23.7 - 24.2)		23.5 (23.2 - 23.8)	
Smoker			0.094		
yes	787 (37)	23.2 (22.6 - 23.8)		not done	
no	1322 (63)	23.8 (23.7 - 23.9)		not done	
Diabetes			0.003		
yes	697 (33)	23.0 (22.4 - 23.6)		not done	
no	1412 (67)	23.8 (23.8 - 23. 9)		not done	
Heart failure					
yes	365 (17)	22.9 (22.4 - 23.4)	0.002	not done	
no	1744 (83)	23.8 (23.7 - 23.9)		not done	
ASA physical status					<0.001
1	41 (1.9)	28.0 (26.3 - 29.7)	<0.001	25.9 (25.1 - 26.6)	
2	530 (25)	25.0 (24.7 - 25.3)		24.4 (24.0 - 24.7)	
3	1024 (51)	23.7 (23.1 - 24.3)		23.6 (23.2 - 23.9)	
4	510 (24)	22.0 (21.4 - 22.5)		23.0 (22.6 - 23.3)	
Duration of Surgery, h			<0.001		<0.001
<2.0	581 (29)	25.9 (25.7 - 26.1)		25.6 (25.2 - 26.0)	
2.0-2.99	412 (20)	24.0 (23.5 - 24.5)		24.0 (23.7 - 24.3)	
3.0-3.99	551 (26)	22.9 (22.8 - 23.1)		23.1 (22.7 - 23.4)	
≥4.0	565 (27)	21.9 (21.4 - 22.3)		22.0 (21.6 - 22.5)	

†covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table 3. Median (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value†
Myocardial infarction (120 [6.5])	1846	20.8 (19.2 - 22.4)	23.8 (23.7 - 23.9)	<0.001
Stroke (13 [0.7])	1846	10.1 (2.5 - 17.7)	23.8 (23.5 - 24.0)	<0.001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.4 - 25.9)	23.7 (23.5 - 24.0)	0.012
Cardiac arrest (3 [0.2])	1846	17.7 (0.9 - 34.5)	23.7 (23.5 - 24.0)	0.018
Surgical site infection (129 [7.0])	1846	21.0 (19.0 - 23.0)	23.8 (23.7 - 23.9)	<0.001
Any of the above (263 [14.2])	1846	20.5 (19.1 - 21.9)	23.9 (23.8 - 23.9)	<0.001
Hospital readmission (150 [7.1])	2090	17.9 (16.3 - 19.5)	23.9 (23.8 - 23.9)	<0.001

† P values calculated using the quasi- likelihood ratio test.

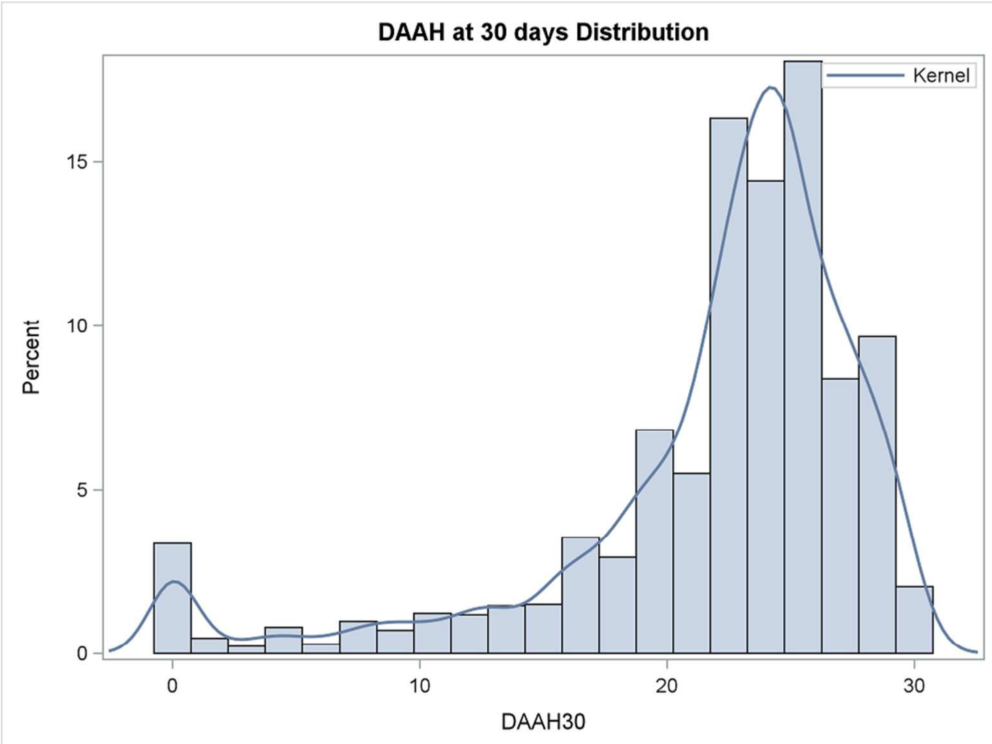


Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

84x63mm (300 x 300 DPI)

Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Days Alive and at Home after Surgery

Proposed Method of Calculation of "Days at Home within 30 days of Surgery" (DAH_{30})

DAH_{30} is a composite measure incorporating hospital length of stay in the hospital following the index surgery, re-admission to either the index or any other hospital, and including post-acute hospital discharge to a rehabilitation centre/hospital or other nursing facility, and early deaths after surgery, into a single outcome metric.

DAH_{30} is a numerical outcome measure that provides greater statistical power to detect clinically important differences in outcome. It is likely that a 0.5 day difference would be clinically important and valued by most people. A hospital bed day has been costed at £400 by the NHS in the UK, and $1800 in the US. It has the potential to increase the available hospital beds by about 8%.

By its very nature, DAH_{30} will be left-skewed with a spike at 0 (reflecting in-hospital deaths and those still admitted to hospital or other nursing facility at 30 days after surgery).

DAH_{30} is calculated using mortality and hospitalisation data from the date of the index surgery (= Day 0). For example, if a patient died on day 2 after their surgery whilst still an inpatient, they would be assigned 0 $DAH_{30;}$ if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they would be assigned 20 DAH_{30}. If a patient has complications and spends 16 days in hospital, and then is transferred to a nursing facility for rehabilitation, and spend 24 days there before finally being discharged to their own home, they would be assigned 0 DAH_{30}. (30-16-24 = -10, but the minimum value of DAH_{30} should be zero*).

Patients having a planned re-admission (eg. removal of a stent or secondary closure of a fistula) within 30 days of surgery should have these days subtracted from the total DAH_{30}. That is, if a patient is discharged from hospital on Day 13, and is electively re-admitted two weeks later (Day 27) for a further 2 days, their DAH_{30} will be calculated as 30-13-2 (=15).

Important: If a patient dies within 30 days of surgery, irrespective of whether they have spent some time at home, DAH_{30} should be scored as zero (0).

*an alternative would be to use DAH_{90} (up to 90 days after surgery) as an outcome metric in circumstances where a longer postoperative recovery is expected.

Table S1. Trial Data Sources

Trial	N	Reference
1. Tranexamic acid in coronary artery surgery	613	N Engl J Med 2016; Oct
2. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial	516	Lancet 2014; 384:1446-54.
3. An enhanced recovery after surgery (ERAS) program for hip and knee arthroplasty	310	Med J Aust 2015; 202:363-8.
4. Experience of an enhanced recovery after surgery (ERAS) program for elective abdominal surgery	71	Anaesth Intensive Care 2012; 40:450-9.
5. The measurement of disability-free survival after surgery	163	Anesthesiology 2015; 122:524-36.
6. Perioperative management of patients treated with angiotensin converting enzyme inhibitors and angiotensin II receptor blockers: a quality improvement audit	263	Anaesth Intensive Care 2016; 44:346-52.
7. Restrictive versus liberal fluid therapy in major abdominal surgery	173	ClinicalTrials.gov NCT01424150

Figure S1. The impact of the quantile (50th – 75th percentile) choice for days at home up to 30 days (here, DAAH30) on the associations of patient age category, ASA physical status and surgical duration, demonstrating the covariates are reasonably stable over this range.

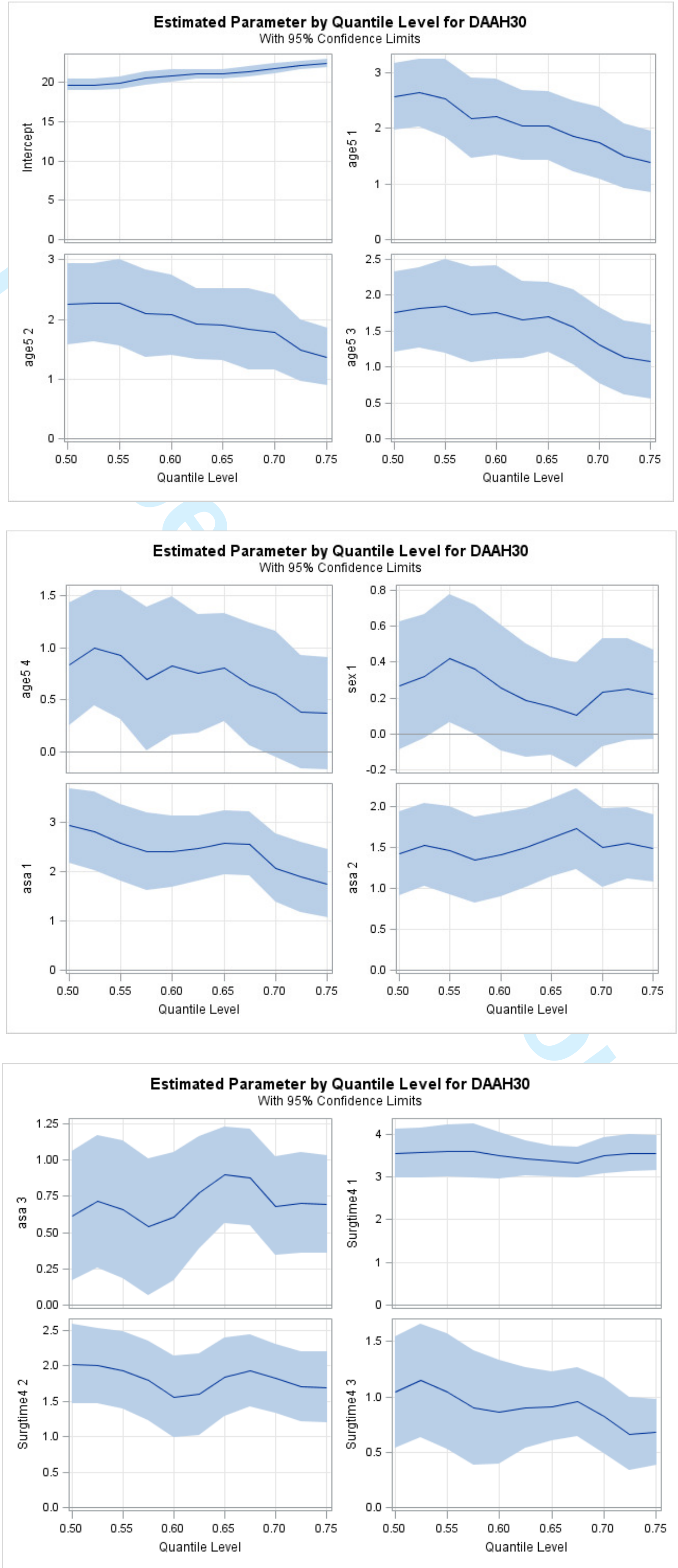


Table S2. Third Quartile (Q3) Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw Q3 DAH_{30} (95% CI)	P value	Adjusted Q3 DAH_{30} (95% CI)*	P-value
Patient age					
<50 years	220 (11)	27.2 (26.5 , 27.9)	<.0001	26.1 (25.8 , 26.5)	<0.0001
50-60 years	396 (19)	25.9 (25.5 , 26.4)		26.1 (25.9 , 26.4)	
60-70 years	612 (29)	25.7 (25.0 , 26.4)		25.8 (25.6 , 26.1)	
70-80 years	653 (31)	25.0 (24.6 , 25.4)		25.1 (24.8 , 25.4)	
≥80 years	228 (11)	24.8 (24.3 , 25.3)		24.7 (24.1 , 25.4)	
Sex					
Male	1427 (68)	25.1 (24.8 , 25.4)	<.0001	25.6 (25.5 , 25.8)	0.146
Female	682 (32)	26.2 (25.6 , 26.8)		25.4 (25.2 , 25.7)	
Smoker					
yes	787 (37)	25.0 (24.8 , 25.1)	<.0001	not done	
no	1322 (63)	26.0 (25.7 , 26.2)		not done	
Diabetes					
yes	697 (33)	25.8 (25.1 , 26.5)	>.99	not done	
no	1412 (67)	25.8 (25.6 , 26.0)		not done	
Heart failure					
yes	365 (17)	25.9 (25.2 , 26.7)	0.39	not done	
no	1744 (83)	25.8 (25.4 , 26.2)		not done	
ASA physical status					
1	41 (1.9)	29.0 (28.8 , 29.3)	<.0001	26.6 (26.0 , 27.2)	<0.0001
2	530 (25)	27.0 (26.9 , 27.1)		26.3 (26.0 , 26.6)	
3	1024 (51)	25.8 (25.3 , 26.3)		25.5 (25.3 , 25.8)	
4	510 (24)	23.9 (23.8 , 24.0)		24.8 (24.5 , 25.1)	
Duration of Surgery, h					
<2.0	581 (29)	28.1 (27.7 , 28.6)	<.0001	27.6 (27.3 , 28.0)	<0.0001
2.0-2.99	412 (20)	26.1 (25.6 , 26.5)		25.8 (25.4 , 26.2)	
3.0-3.99	551 (26)	24.8 (24.7 , 24.9)		24.8 (24.5 , 25.0)	
≥4.0	565 (27)	23.9 (23.8 , 23.9)		24.1 (23.8 , 24.4)	

The effect of the different covariates were largely consistent across a large range of meaningful percentile values (e.g. 50th – 75th) with a slightly smaller effect for age categories as the percentile gets higher but for simplicity we only present the results for Q3 (75th percentile). This percentile is also close to the main mode of the distribution.

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table S3. Third Quartile (Q3) (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	22.9 (22.2 - 23.5)	25.8 (25.4 - 26.2)	<0.0001
Stroke (13 [0.7])	1846	18.9 (10.0 - 27.8)	25.2 (24.6 - 25.7)	0.019
Pulmonary embolism (7 [0.4])	1846	23.1 (16.1 - 30.1)	25.2 (24.6 - 25.7)	0.19
Cardiac arrest (3 [0.2])	1846	20.1 (8.0 - 32.1)	25.2 (24.6 - 25.7)	0.052
Surgical site infection (129 [7.0])	1846	24.8 (23.7 - 26.0)	25.3 (24.7 - 25.9)	<0.0001
Any of the above (263 [14.2])	1846	23.7 (23.0 - 24.5)	25.8 (25.6 - 26.1)	<0.0001
Hospital readmission (150 [7.1])	2090	21.7 (20.8 - 22.7)	25.9 (25.8 - 26.0)	<0.0001

[a] P values calculated using likelihood ratio test.

Table S4. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.

Surgery	No. admitted to a rehabilitation hospital (%)	Mean (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.7-22.9)
Orthopaedic (n=289)	122 (42)	21.9 (21.2-22.6)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (24.1-25.8)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.9-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

Table S5. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.∞

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value#
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.5 - 25.2)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.5 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.2 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.4 (20.4 - 22.4)	
Sex			0.90		0.0052
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.4 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			>0.99		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.6 - 23.4)			
Diabetes			0.091		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.6 - 23.8)			
Heart failure			0.16		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status					
1	41 (1.9)	27.9 (26.1 - 29.7)		25.3 (24.3 - 26.3)	<0.0001
2	530 (25)	24.9 (24.6 - 25.1)	<0.0001	24.0 (23.6 - 24.5)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.3)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.3)		23.6 (23.2 - 24.0)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

#P values calculated using the quasi-likelihood ratio test.

∞ If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S6. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.*

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.6 - 21.5)	23.1 (22.6 - 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.7 - 16.5)	23.0 (22.8 - 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.0 - 26.3)	23.0 (22.7 - 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.7 - 29.4)	23.0 (22.8 - 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (18.9 - 22.6)	23.1 (22.6 - 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 - 20.8)	23.7 (23.3 - 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 - 19.0)	23.7 (23.3 - 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.
[b] days calculated for those without readmission after excluding postoperative deaths.

* If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-}rehab}$ is set to 0 to avoid negative values.

Table S7. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.*

Surgery	No. admitted to a rehabilitation hospital (%)	Median (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.6-22.9)
Orthopedic (n=289)	122 (42)	20.9 (17.5-24.4)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (23.9-26.0)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.8-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

*If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S8. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.4 - 25.3)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.6 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.3 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.5 (20.5 , 22.4)	
Sex			0.84		0.0065
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.3 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			0.92		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.5 - 23.4)			
Diabetes			0.12		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.5 - 23.8)			
Heart failure			0.19		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status			<0.0001		<0.0001
1	41 (1.9)	27.9 (26.0 - 29.8)		25.3 (24.2 - 26.3)	
2	530 (25)	24.9 (24.6 - 25.1)		24.1 (23.6 - 24.6)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.4)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.4)		23.6 (23.2 - 24.1)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery.
#If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S9. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.5 , 21.6)	23.1 (22.6 , 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.4 , 16.9)	23.0 (22.8 , 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.3 , 26.0)	23.0 (22.7 , 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.4 , 29.8)	23.0 (22.8 , 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (19.0 , 22.5)	23.1 (22.6 , 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 , 20.8)	23.7 (23.3 , 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 , 18.9)	23.7 (23.3 , 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.

[b] Days calculated for those without readmission after excluding postoperative deaths. If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

BMJ Open

Validation of Days at Home as an Outcome Measure after Surgery: a cohort study of clinical trial hospital, discharge and 30-day follow-up data

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-015828.R2
Article Type:	Research
Date Submitted by the Author:	26-May-2017

Complete List of Authors:	Myles, Paul; Alfred Hospital and Monash University, Anaesthesia and Perioperative Medicine Shulman, Mark; Alfred Hospital Heritier, Stephane; School of Public Health and Preventive Medicine, Monash University, Department of Epidemiology and Preventive Medicine Wallace, Sophie; Alfred Hospital McIlroy, David; Alfred Hospital, Department of Anaesthesia and Perioperative Medicine McCluskey, Stuart; University Health Network, Anesthesia and Pain Medicine Sillar, Isabella; Alfred Hospital Forbes, Andrew; Monash University

Primary Subject Heading:	Anaesthesia
Secondary Subject Heading:	Surgery, Epidemiology
Keywords:	STATISTICS & RESEARCH METHODS, outcome, perioperative medicine, Clinical trials < THERAPEUTICS

Validation of Days at Home as an Outcome Measure after Surgery: a cohort study of clinical trial hospital, discharge and 30-day follow-up data

Paul S. Myles,[1,2,3] Mark A. Shulman,[1] Stephane Heritier,[3] Sophie Wallace,[1] David R. McIlroy,[1,2] Stuart McCluskey,[4] Isabella Sillar,[2] Andrew Forbes[3]

[1]Department of Anaesthesia and Perioperative Medicine, Alfred Hospital, Melbourne, Australia
[2]Department of Anaesthesia and Perioperative Medicine, Monash University, Melbourne, Australia
[3]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia
[4]Toronto General Hospital and University of Toronto, Toronto, ON, Canada

ADDRESS FOR CORRESPONDENCE
Paul S. Myles
Professor and Chair
Department of Anaesthesia and Perioperative Medicine
Alfred Hospital, Commercial Road, Melbourne, Victoria, 3004, Australia

Email: p.myles@alfred.org.au

Word count: 3035

Competing interest statement - All authors declare that the answer to the questions on the competing interest form are all No and therefore have nothing to declare.

Funding - The Australian and New Zealand College of Anaesthetists; and the Australian National Health and Medical Research Council Practitioner Fellowship (Prof Myles).

ABSTRACT

OBJECTIVE To evaluate "days at home up to 30 days after surgery" (DAH_{30}) as a patient-centred outcome measure.

DESIGN Prospective cohort study.

DATA SOURCE Using clinical trial data (7 trials, 2109 patients) we calculated DAH_{30} from length of stay, re-admission, discharge destination, and death up to 30 days after surgery.

MAIN OUTCOME The association between DAH_{30} and serious complications after surgery.

RESULTS One or more complications occurred in 263 of 1846 (14.2%) patients, including 19 (1.0%) deaths within 30 days of surgery; 245 (11.6%) patients were discharged to a rehabilitation facility and 150 (7.1%) were readmitted to hospital within 30 days of surgery. The median DAH_{30} was significantly less in older patients (P<0.001), those with poorer physical functioning (P<0.001), and in those undergoing longer operations (P<0.001). Patients with serious complications had less days at home than patients without serious complications (20.5 [95% CI, 19.1 to 21.9] vs 23.9 [95% CI, 23.8 to 23.9] P<0 .001), and had higher rates of readmission (16.0% vs. 5.9%; P < 0.001). After adjusting for patient age, sex, physical status and duration of surgery, the occurrence of postoperative complications was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.001).

CONCLUSIONS DAH_{30} has construct validity and is a readily-obtainable generic patient-centred outcome measure. It is a pragmatic outcome measure for perioperative clinical trials.

Strengths and limitations of the study

- This study integrates length of stay, re-admission, discharge destination, and early deaths after surgery into a single outcome metric, "days at home up to 30 days after surgery" (DAH_{30})
- Patients hope to recover quickly after surgery, free of complications and need for re-admission; DAH_{30} is thus a patient-centred outcome
- Accurate calculation of DAH_{30} requires knowledge of post-discharge location (home or nursing facility) and any re-admissions at the index or other hospitals
- Because early deaths heavily influence the DAH_{30} metric, this information should be additionally reported if, say, the incidence exceeds 10%

Introduction

Surgery and other interventional procedures are intended to relieve symptoms and in many cases prolong life. But surgery is not risk-free; perioperative complications can impair patient recovery resulting in prolonged hospitalization, short or longer term disability, and sometimes poor survival. A wide variety of outcome measures have been used to quantify each of these aspects of the postoperative experience but few provide a broad, patient-centred perspective of effective and efficient care;[1] these are needed to better inform the current shift towards value-based healthcare.[2 3]

Patient-centred care requires clinicians to consider outcomes that matter most to patients. That is, the patient's experience of their illness, quality of life, and functioning; their values, preferences and goals for health care.[4] Loss of the ability to live independently is a major concern for the elderly;[5 6] it is clearly a patient-centred outcome, and has been associated with postoperative readmissions and death after hospital discharge.[5]

Specific peri-procedural complications such as surgical site infection, respiratory failure, delirium, and myocardial infarction are clearly important to patients and physicians alike, but reliable and consistent detection is problematic. In any case such information is an incomplete description of the overall success of surgery and other perioperative care, and does not describe the impact of such complications on functioning and need for institutionalization. Similar challenges occur when nominating endpoints in clinical trials, including a lack of standardisation,[7] need for adjudication, and uncertainty about the overall health impact of each endpoint on a patient's recovery. There is a growing acceptance that

outcome measures used in clinical trials should be determined in partnership by patients and physician-researchers, aiming to identify outcomes that are important to patients.[8]

“Days alive and out of hospital” has been shown to be a readily quantifiable and patient-centred outcome measure in some chronic cardiovascular conditions such as heart failure and atrial fibrillation,[9-11] and in geriatric medicine,[12] but it has not been used as an outcome measure in perioperative trials. Home discharge has been proposed as a proxy for a patient’s recovery after surgery,[13] and is estimated when using the American College of Surgeons’ Surgical Risk Calculator,[14] but this does not account for readmissions or early deaths, although the latter collects and reports some of this information.[15]

Our own work and that of others have shown that early return home after surgery,[6 16-18] and medical illnesses such as stroke,[19 20] is highly valued by patients but could be undermined if the patient were to be transferred to another type of nursing facility. A more favourable perioperative outcome measure should account for both the initial hospital stay associated with the index surgery, rehospitalisation due to post-discharge complications, discharge to institutional care, and early deaths.

We thus chose to evaluate the utility of “days (alive and) at home” within 30 days of surgery (DAH_{30}) in the surgical/perioperative setting as a patient-centred outcome measure for perioperative clinical trials and quality improvement activities. Our hypothesis was that DAH_{30} would be lower in higher risk patients, those undergoing more extensive surgery, and in those with complications after surgery (i.e. it has construct validity).

Methods

This manuscript was written in adherence to the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement.[21]

Study Design and Data Sources

Data were obtained from each of seven recently completed clinical trials that prospectively enrolled patients undergoing various types of elective and emergency surgery at the Alfred Hospital in Melbourne, Australia. The cohort consisted of four multicentre randomised trials and three before-and-after studies (see Table S1 in the Supplementary Appendix).[22-29] For each trial we collected a comparable set of patient demographic and perioperative characteristics, and clinical outcome measures, including complete hospital discharge, discharge destination (home, rehabilitation facility, nursing home) and re-admission data. All but one study[28] prospectively recorded re-admission data; for the latter study we could obtain this information retrospectively from our hospital information system. Both the present study and each of the original trials received institutional ethics committee approval.

Patients

Patients 18 years and older undergoing an elective or non-elective inpatient operation enrolled in one of the aforementioned trials were included. Study inclusion criteria were established for the original studies and typically identified those at increased risk of postoperative complications. In all cases patients provided informed consent before enrolment in the original trials.

Patient involvement

Hospital patients have previously indicated the importance of returning home after hospitalisation for medical or surgical conditions, [6 16-20] but we did not involve patients or their carers in the design or conduct of this study.

Risk Factors and Outcomes

Perioperative data included patient demographics, comorbidity, functional status, type and duration of surgery, hospital length of stay, hospital readmission(s), and in all but one study[28] we prospectively collected selected complications at 30 days after surgery: wound infection, myocardial infarction, stroke, pulmonary embolism, cardiac arrest, and death.

Hospital discharge data were used to calculate hospital length of stay. Whether the patient was discharged from hospital to their home or to a nursing facility was obtained from the electronic medical record, but for those admitted to a rehabilitation facility we were unable to ascertain the number of days admitted before eventual discharge home. For those readmitted to hospital we combined the original length of stay with subsequent hospital stay(s) to calculate total length of stay within 30 days postoperatively.

DAH_{30} was calculated using mortality and hospitalisation data from the date of the index surgery (Day 0). For example, if a patient died on day 2 after their surgery, they were assigned 0 DAH_{30}, if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they were assigned 20 DAH_{30}. If a patient died within 30 days of surgery, irrespective of whether they

had spent some time at home, DAH_{30} was scored as zero (0). Further explanation is provided in the Supplementary Appendix.

Patients are commonly admitted to a post-acute hospital rehabilitation centre after lower limb arthroplasty and cardiac surgery in our setting; some frail and elderly patients are also transferred for ongoing convalescence. We were unable to reliably collect secondary length of stay for rehabilitation facilities - we thus did two secondary analysis, assuming the length of stay in a rehabilitation facility was 5 or 14 extra days. That is, $DAH_{30\text{-rehab5}}$ was calculated as DAH_{30}-5, and $DAH_{30\text{-rehab14}}$ was calculated as DAH_{30}-14, in secondary analyses.

For the multicentre trials,[22-24] a 12-lead electrocardiograph was recorded preoperatively and on day 1 and 3 after surgery. Blood for troponin (or if unavailable, creatine kinase-myocardial band) measurement was collected at 6 to 12 hours after surgery and on the first three postoperative days. In all trials laboratory tests were otherwise ordered if clinically indicated. Each complication was defined within the original study protocol and in all cases a consistent definition was used. In brief, surgical site infection was confirmed if associated with purulent discharge, with or without a positive microbial culture; or pathogenic organisms isolated from aseptically obtained microbial culture,[30] although the most recent trial[27] included documentation of a physician's diagnosis in this definition.[31] Pneumonia was confirmed by a new pulmonary infiltrate reported by chest x-ray or computerized tomography, in association with at least one of: temperature >38°C, white cell count >12,000/ml, or positive sputum culture that was not heavily contaminated with oral flora or that corresponded with positive blood cultures. Myocardial infarction was defined according to the third universal definition,[32] requiring elevated cardiac biomarker plus at least one of the

following: (i) ischaemic symptoms, (ii) pathological Q waves, (iii) electrocardiographic changes indicative of ischemia, (iv) coronary artery intervention or (v) new wall motion abnormality on echocardiography or scanning; or autopsy finding of myocardial infarction. The threshold for significant elevated troponin was the hospital laboratory's 99th percentile of a normal reference population (upper reference limit), according to recent recommendations.[33] Stroke was confirmed if a new neurological deficit persisting for at least 24 hours, verified by neurologist assessment and/or computerized tomography or magnetic resonance imaging.

Statistical Analysis[34 35]

Data were first merged and checked for inconsistencies. Patient age was grouped into 10-year categories, and hourly cut-points for duration of surgery (2, 3, and 4 h) were created to generate approximately similar group sizes and facilitate clinical interpretation. DAH_{30} was analysed using quantile regression.[36] This approach, well known in econometrics where it was initially introduced, allows the modelling of any quantile of a continuous endpoint, here DAH_{30}, as a linear combination of the covariates. As DAH_{30} is left skewed with a spike at zero, it is more relevant to model the median (or alternatively, the 75th percentile) that is closer to the major distribution mode and directly interpretable. The choice of the quantile(s) to be analysed can be prespecified or a range of values selected for their meaningfulness or exploratory purposes. Here the range 50th-75th percentile was deemed relevant. No assumption on the true distribution of the endpoint is required. The asymptotic distribution of the parameter estimates can be derived but depends on some unknown density estimate. In general, resampling methods are recommended to obtain confidence intervals (CIs).[37 38] Raw and adjusted medians and their 95% CIs obtained by bootstrapping as implemented in Stata with 1000 replicates were reported for key predictors. The adjusted models included age by 10-year categories, sex, American Society of Anesthesiologists (ASA) physical status score, surgery time (< 2h, 2.0 - 2.99, 3.0 -3.99, ≥4.0). A goodness of fit test[39] comparing this model to the full model including the same predictors plus smoking, heart failure and diabetes was not any better (P=0.36). A global test of effect of any key predictor was carried out using a quasi-likelihood ratio test.[39] Quantile regression was also used to test median differences between those with and without complications, and by postoperative complications. Supplementary analyses were done for the 75th percentile (Q3). All analyses were done using Stata 14.0 except the quasi-likelihood ratio test analysis that is only available in SAS. All tests were two-sided and performed at level α=0.05; no correction was made for multiple comparisons.

Results

A total of 2109 eligible patients 18 years and older were enrolled into clinical trials and underwent inpatient operations at the Alfred Hospital between March 2006 and September 2016. The number of patients enrolled in each of the trials is detailed in the Supplement (Supplementary Table 1). The cohort included 1427 male patients (67.7%) with a mean (SD) age of 65 (12) years who underwent a range of inpatient operations (Table 1). Most operations were cardiac surgical procedures (679 [32.2%]), followed by general (489 [23.2%]), urologic (315 [14.9%]), and neurosurgical procedures (220 [10.4%]).

There was a bimodal, skewed distribution of DAH_{30} (Figure 1). The spike at zero consisted of 19 patients (1.0%) that died, and 40 patients remaining in hospital at least 30 days after

surgery. DAH_{30} and rates of admission to a rehabilitation centre varied according to type of surgery (Table 2).

One or more complications occurred in 263 (14.2%) patients. Overall, 245 (11.6%) patients were admitted to a rehabilitation facility and 150 (7.1%) were readmitted within 30 days of surgery. The median DAH_{30} was 23.7 (95% CI, 23.5 to 24.0), but this varied according to type of surgery (Table 1).

The median DAH_{30} was significantly less in older patients, current smokers, diabetics, those with poorer physical functioning, and undergoing longer operations (Table 2). These associations remained after adjustment for all of these covariates and patient sex (Table 2). The individual complications of myocardial infarction, stroke, pulmonary embolism, and surgical site infection were each associated with shorter DAH_{30} (Table 3) in a raw analysis. Hospital readmission was also a factor, decreasing median DAH_{30} when compared with those not readmitted to hospital, 17.9 (95% CI, 16.3 to 19.5) vs 23.9 (95% CI, 23.8 to 23.9), respectively (P<0.0001).

After adjusting for patient age, sex, ASA physical status and duration of surgery, the occurrence of any postoperative complication was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.0001).

Supplementary Analyses

The above findings were consistent when analysing the 3rd quartile distributions and differences (Tables S2-S4 in the Supplementary Appendix), and after accounting for the additional loss of days at home because of admission to a rehabilitation centre (Tables S5 – S9 in the Supplementary Appendix).

Discussion

We found that DAH_{30} has construct validity and is a readily-obtainable patient-centred outcome measure that could be used to better inform patients and physicians when planning surgery. Unlike previous related measures, DAH_{30} accounts for each of delayed hospital discharge because of postoperative complications, discharge to a rehabilitation centre or other post-acute care nursing facility, rehospitalisations, and postoperative deaths. It thus captures much of the surgical experience, integrating efficacy, quality and safety, and thus reflecting value-based care. It can also be risk-adjusted for bench-marking purposes. DAH_{30} will be maximized when patients recover free of complications after surgery, with optimal comfort and functioning - aligning with patient values and preferences, and goals for health care.[4]

Although concerns are frequently raised about the usefulness of hospital length of stay as an outcome measure after surgery, largely because of social factors and reluctance to discharge on weekends, it mostly adds variance (background noise) in clinical trials and is not biased. Hospital stay is a reasonable surrogate for quality and speed of recovery after surgery,[13 40-42] and it has marked resource/cost implications. Most patients want to go home as soon as possible – it is a desired outcome in and of itself.

The US has a triple aim of improving the healthcare system: improving the patient experience of care, improving the health of populations, and reducing per capita costs of healthcare.[43] DAH_{30} seems to be useful, generic metric in this regard.[44] DAH_{30} is a measure of the overall burden of care, both in hospital and post-discharge. The perceived success of a hospital discharge plan as perceived by the patient and their principal carer depends on clear communication and meeting expectations.[45] DAH_{30} offers transparency and opportunities for benchmarking performance, both of which are important components of quality improvement.[1 3] It may influence alternative payment contracts for hospitals.

Postoperative complications add to hospital costs and increase length of stay.[46] Higher episode payments at "lower-quality" hospitals have been attributed to higher rates of complications, 30-day readmissions, and post-discharge ancillary care.[46] Serious postoperative complications are both strongly associated with readmission,[5 17] increasing the risk by 6.7-fold, and loss of independence.[5] Readmission is a frequent, costly, and sometimes life-threatening event that is associated with gaps in follow-up care.[15 17 47] Readmission after surgery is thus an established quality indicator. Trends in readmissions suggest that US hospitals are responding to incentives to reduce readmissions under the Affordable Care Act.[48 49] Hospital readmission rates are not highly correlated with mortality rates, [50] so they offer an independent and more sensitive measure of quality. Even though some readmissions are due to chronic medical conditions,[47] optimal perioperative care should keep these to a minimum and such improvements should be reflected in more DAH_{30}.

Enhanced recovery after surgery programs are designed to reduce complications and shorten length of stay. But this sometimes comes at the cost of increased hospital re-admissions.[51 52] The measurement and reporting of DAH_{30} would identify this and hopefully encourage further quality improvement. Planned discharge to a rehabilitation facility sometimes forms part of an enhanced recovery pathway, and in any case may not be seen by the patient or their family as indicating a poor outcome. Therefore, calculation of DAH_{30} in some studies could incorporate days spent in a rehabilitation facility as equivalent to being home. In contrast, unplanned admission to a rehabilitation facility would indicate poor care or adverse outcome, and this should be retained in the calculation of DAH_{30}. Care should be taken to avoid missing out-of-network hospitalizations, particularly if relying on hospital system electronic medical records. The latter will otherwise enhance the efficiency of data collection.

Composite endpoints used in perioperative trials are often flawed,[53-55] typically used to increase the number of events in order to enhance statistical power. DAH_{30}, as a numerical patient-centred measure, provides more statistical power, can be reliably measured and has direct patient-centredness. Although some postoperative complications and poor survival can manifest many months after surgery in those recovering from major surgery or critical illness,[29 56 57] extending measurement out to 90 days after surgery (i.e. DAH_{90}) may not necessarily provide new or different information because the extra burden and costs of further data collection may outweigh the benefits of the extra information obtained. In addition, disease progression or other aspects of life may confound outcome evaluation of perioperative care.

Our study has several limitations. First, this was a single-centre study of clinical trial data collected for other purposes. Second, postoperative in-hospital deaths have a major influence on the calculation of DAH_{30}; this is arguably appropriate because perioperative studies should weight this as the most extreme adverse outcome. More sophisticated modelling could jointly model the risk of death and DAH_{30} in those discharged alive, and such modelling would be particularly important if the in-hospital mortality rate is moderate or greater. Third, different health care settings can be expected to have varied casemix and hospital discharge processes, and hospital discharge may be delayed because of social and process issues unrelated to complications or quality of care. DAH_{30} should therefore be risk-adjusted.[58] Fourth, DAH_{30} doesn't provide specific information on which aspects of in-hospital or post-discharge management influences where patients reside after hospitalization, or the post-discharge use and effectiveness of family physician or other health care resources. Fifth, DAH_{30} is an overall measure of recovery profile and does not inform us about specific complications, level of functioning or wellbeing. Such aspects should also be included when conducting outcome studies. Sixth, obtaining accurate data on days spent in a rehabilitation facility relies on further follow-up or accurate electronic records. Future studies using DAH_{30} should prospectively plan to reliably obtain such data.

CONCLUSIONS

DAH_{30} has construct validity and is a readily-obtainable, generic, patient-centred outcome measure that can better inform patients and physicians when planning surgery. It is a suitable outcome measure for both quality improvement and perioperative clinical trials. DAH_{30} accounts for prolonged hospital stay, discharge to any post-acute care nursing facility,

rehospitalizations, and early deaths. It thus captures much of the patient-centred experience, and will be maximal when effective and efficient care is achieved.

Contributor statement: PM designed the study, oversaw the ethics application, devised the statistical analysis plan, and drafted and revised the paper. He is guarantor. MS provided intellectual input into the study design, and drafted and revised the paper. SH analysed the data and drafted and revised the paper. SW prepared the ethics application, monitored the data entry and checking, and drafted and revised the paper. DM provided intellectual input into the study design, and drafted and revised the paper. SM provided intellectual input into the study design, and drafted and revised the paper. IS retrieved and entered all study data, and revised the paper. AF contributed to the statistical analysis, and drafted and revised the paper.

Transparency declaration: The lead author* affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Acknowledgment: The authors would like to thank the study participants for their interest and preparedness to consent to the original trials. PM is supported in part by Practitioner Fellowships from the Australian National Health and Medical Research Council (NHMRC).

Funding: This work was supported by the Australian NHMRC, the New Zealand Health Research Council, and the Australian and New Zealand College of Anaesthetists, and Monash University (Melbourne, Australia).

Additional data: No additional data available.

Competing interests: None of the authors have any conflicts of interest

Ethics approval: This trial has been approved by the Ethics Committees of Alfred Health, Melbourne, Australia.

References

1. Austin JM, McGlynn EA, Pronovost PJ. Fostering Transparency in Outcomes, Quality, Safety, and Costs. *Jama* 2016 doi: 10.1001/jama.2016.14039 [published Online First: 2016/09/27]
2. Lynn J, McKethan A, Jha AK. Value-Based Payments Require Valuing What Matters to Patients. *JAMA* 2015;314(14):1445-6. doi: 10.1001/jama.2015.8909
3. Porter ME. What is value in health care? *N Engl J Med* 2010;363(26):2477-81. doi: 10.1056/NEJMp1011024 [published Online First: 2010/12/15]
4. Lavallee DC, Chenok KE, Love RM, et al. Incorporating Patient-Reported Outcomes Into Health Care To Engage Patients And Enhance Care. *Health Aff (Millwood)* 2016;35(4):575-82. doi: 10.1377/hlthaff.2015.1362 [published Online First: 2016/04/06]
5. Berian JR, Mohanty S, Ko CY, et al. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg* 2016;151(9):e161689. doi: 10.1001/jamasurg.2016.1689 [published Online First: 2016/07/14]
6. Fried TR, Bradley EH, Towle VR, et al. Understanding the treatment preferences of seriously ill patients. *N Engl J Med* 2002;346(14):1061-6. doi: 10.1056/NEJMsa012528
7. Goldfarb M, Drudi L, Almohammadi M, et al. Outcome Reporting in Cardiac Surgery Trials: Systematic Review and Critical Appraisal. *J Am Heart Assoc* 2015;4(8):e002204. doi: 10.1161/jaha.115.002204 [published Online First: 2015/08/19]
8. Chalmers I, Clarke M. Outcomes that matter to patients in tombstone trials. *Lancet* 2001;358(9293):1649. doi: S0140673601066892 [pii] [published Online First: 2001/11/22]
9. Ariti CA, Cleland JG, Pocock SJ, et al. Days alive and out of hospital and the patient journey in patients with heart failure: Insights from the candesartan in heart failure: assessment of reduction in mortality and morbidity (CHARM) program. *Am Heart J* 2011;162(5):900-6. doi: 10.1016/j.ahj.2011.08.003
10. Wasywich CA, Gamble GD, Whalley GA, et al. Understanding changing patterns of survival and hospitalization for heart failure over two decades in New Zealand: utility of 'days alive and out of hospital' from epidemiological data. *Eur J Heart Fail* 2010;12(5):462-8. doi: 10.1093/eurjhf/hfq027
11. Xian Y, Wu J, O'Brien EC, et al. Real world effectiveness of warfarin among ischemic stroke patients with atrial fibrillation: observational analysis from Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research (PROSPER) study. *BMJ* 2015;351:h3786. doi: 10.1136/bmj.h3786
12. Ellis G, Whitehead MA, Robinson D, et al. Comprehensive geriatric assessment for older adults admitted to hospital: meta-analysis of randomised controlled trials. *Bmj* 2011;343:d6553. doi: 10.1136/bmj.d6553 [published Online First: 2011/10/29]
13. Hyder JA, Hirschberg RE, Nguyen LL. Home discharge as a performance metric for surgery. *JAMA Surg* 2015;150(2):96-7. doi: 10.1001/jamasurg.2014.1725 [published Online First: 2014/12/05]
14. Hyder JA, Wakeam E, Habermann EB, et al. Derivation and validation of a simple calculator to predict home discharge after surgery. *J Am Coll Surg* 2014;218(2):226-36. doi: 10.1016/j.jamcollsurg.2013.11.002
15. Merkow RP, Ju MH, Chung JW, et al. Underlying reasons associated with hospital readmission following surgery in the United States. *JAMA* 2015;313(5):483-95. doi: 10.1001/jama.2014.18614
16. Boney O, Bell M, Bell N, et al. Identifying research priorities in anaesthesia and perioperative care: final report of the joint National Institute of Academic Anaesthesia/James Lind Alliance Research Priority Setting Partnership. *BMJ Open* 2015;5(12):e010006. doi: 10.1136/bmjopen-2015-010006 [published Online First: 2015/12/18]
17. Hinami K, Bilimoria KY, Kallas PG, et al. Patient experiences after hospitalizations for elective surgery. *Am J Surg* 2014;207(6):855-62. doi: 10.1016/j.amjsurg.2013.04.014

18. Burns KE, Jacob SK, Aguirre V, et al. Stakeholder Engagement in Trial Design: Survey of Visitors to Critically Ill Patients Regarding Preferences for Outcomes and Treatment Options during Weaning from Mechanical Ventilation. *Ann Am Thorac Soc* 2016;13(11):1962-68. doi: 10.1513/AnnalsATS.201606-445OC [published Online First: 2016/09/07]
19. Hannah D, Lindholm B, Maisch L. Certain uncertainty: life after stroke from the patient's perspective. *Circ Cardiovasc Qual Outcomes* 2014;7(6):968-9. doi: 10.1161/CIRCOUTCOMES.114.001315
20. Xian Y, O'Brien EC, Fonarow GC, et al. Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research: Implementing the patient-driven research paradigm to aid decision making in stroke care. *Am Heart J* 2015;170(1):36-45, 45.e1-11. doi: 10.1016/j.ahj.2015.04.008 [published Online First: 2015/06/22]
21. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370(9596):1453-7. doi: 10.1016/S0140-6736(07)61602-X
22. Myles PS, Leslie K, Chan MT, et al. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial. *Lancet* 2014;384(9952):1446-54. doi: 10.1016/s0140-6736(14)60893-x [published Online First: 2014/08/22]
23. Myles PS, Smith JA, Forbes A, et al. Stopping vs. Continuing Aspirin before Coronary Artery Surgery. *N Engl J Med* 2016;374(8):728-37. doi: 10.1056/NEJMoa1507688
24. Myles PS, Smith JA, Forbes A, et al. Tranexamic acid in coronary artery surgery. *N Engl J Med* 2017;2017(376):136-48.
25. Thompson EG, Gower ST, Beilby DS, et al. Enhanced recovery after surgery program for elective abdominal surgery at three Victorian hospitals. *Anaesth Intensive Care* 2012;40(3):450-9. [published Online First: 2012/05/15]
26. Christelis N, Wallace S, Sage CE, et al. An enhanced recovery after surgery program for hip and knee arthroplasty. *Med J Aust* 2015;202(7):363-8.
27. Glassford NJ, Myles P, Bellomo R. The Australian approach to peri-operative fluid balance. *Curr Opin Anaesthesiol* 2012;25(1):102-10. doi: 10.1097/ACO.0b013e32834decd7 [published Online First: 2011/11/25]
28. Vijay A, Grover A, Coulson T, et al. Perioperative management of patients treated with angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers. *Anaesth Intensive Care* 2016;in press
29. Shulman MA, Myles PS, Chan MT, et al. Measurement of disability-free survival after surgery. *Anesthesiology* 2015;122(3):524-36. doi: 10.1097/ALN.0000000000000586
30. Mangram A, Horan T, Pearson M, et al. Guideline for prevention of surgical site infection, 1999. *Infection Control and Hospital Epidemiology* 1999;20:247-77.
31. Degnim AC, Throckmorton AD, Boostrom SY, et al. Surgical site infection after breast surgery: impact of 2010 CDC reporting guidelines. *Ann Surg Oncol* 2012;19(13):4099-103. doi: 10.1245/s10434-012-2448-6
32. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Circulation* 2012;126(16):2020-35. doi: 10.1161/CIR.0b013e31826e1058

CIR.0b013e31826e1058 [pii] [published Online First: 2012/08/28]

33. Leonardi S, Armstrong PW, Schulte PJ, et al. Implementation of standardized assessment and reporting of myocardial infarction in contemporary randomized controlled trials: a systematic review. *Eur Heart J* 2013;34(12):894-902d. doi: 10.1093/eurheartj/eht003

eht003 [pii] [published Online First: 2013/01/29]

34. WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. Available from www.wma.net/en/30publications/10policies/b3/index.html (accessed 17 October 2012).

35. Caironi P, Tognoni G, Masson S, Fumagalli R, Persenti A, Romero M, et al. Albumin replacement in patients with severe sepsis or septic shock. N Engl J Med. 2014. doi: 10.1056/NEJMoa1305727.
36. Koenker R, Bassett G. Regression quantiles. *Econometrica* 1978;46:33–50.
37. Wu CFJ. Jackknife, bootstrap and other resampling methods in regression analysis. *Ann Stat* 1986;14:1261-350.
38. He X, Hu F. Markov chain marginal bootstrap. *J Am Stat Assoc* 2002;97:783-95.
39. Koenker R, Machado JAF. Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association* 1999;94:1296–310.
40. Gornall BF, Myles PS, Smith CL, et al. Measurement of quality of recovery using the QoR-40: a quantitative systematic review. *Br J Anaesth* 2013;111(2):161-9. doi: 10.1093/bja/aet014

aet014 [pii] [published Online First: 2013/03/09]
41. Liu VX, Rosas E, Hwang J, et al. Enhanced Recovery After Surgery Program Implementation in 2 Surgical Populations in an Integrated Health Care Delivery System. *JAMA Surg* 2017:e171032. doi: 10.1001/jamasurg.2017.1032 [published Online First: 2017/05/12]
42. Yadla S, Ghobrial GM, Campbell PG, et al. Identification of complications that have a significant effect on length of stay after spine surgery and predictive value of 90-day readmission rate. *J Neurosurg Spine* 2015;23(6):807-11. doi: 10.3171/2015.3.spine14318 [published Online First: 2015/09/01]
43. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. *Health Aff (Millwood)* 2008;27(3):759-69. doi: 10.1377/hlthaff.27.3.759
44. Lee VS, Kawamoto K, Hess R, et al. Implementation of a Value-Driven Outcomes Program to Identify High Variability in Clinical Costs and Outcomes and Association With Reduced Cost and Improved Quality. *Jama* 2016;316(10):1061-72. doi: 10.1001/jama.2016.12226 [published Online First: 2016/09/14]
45. Bauer M, Fitzgerald L, Haesler E, et al. Hospital discharge planning for frail older people and their family. Are we delivering best practice? A review of the evidence. *J Clin Nurs* 2009;18(18):2539-46. doi: 10.1111/j.1365-2702.2008.02685.x [published Online First: 2009/04/21]
46. Birkmeyer JD, Gust C, Dimick JB, et al. Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg* 2012;255(1):1-5. doi: 10.1097/SLA.0b013e3182402c17
47. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009;360(14):1418-28. doi: 10.1056/NEJMsa0803563
48. Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, Observation, and the Hospital Readmissions Reduction Program. *N Engl J Med* 2016;374(16):1543-51. doi: 10.1056/NEJMsa1513024
49. Danino JF, Taylor T, Metcalfe CW, et al. Readmission rates and financial penalties after ear, nose and throat surgery: how can we improve? *Br J Hosp Med (Lond)* 2015;76(11):655-7. doi: 10.12968/hmed.2015.76.11.655
50. Hannan EL, Zhong Y, Lahey SJ, et al. 30-Day Readmissions After Coronary Artery Bypass Graft Surgery in New York State. *JACC: Cardiovascular Interventions* 2011;4(5):569-76. doi: http://dx.doi.org/10.1016/j.jcin.2011.01.010
51. Ahmed J, Khan S, Lim M, et al. Enhanced recovery after surgery protocols - compliance and variations in practice during routine colorectal surgery. *Colorectal Dis* 2012;14(9):1045-51. doi: 10.1111/j.1463-1318.2011.02856.x [published Online First: 2011/10/12]
52. Group EC. The Impact of Enhanced Recovery Protocol Compliance on Elective Colorectal Cancer Resection: Results From an International Registry. *Ann Surg* 2015;261(6):1153-9. doi: 10.1097/SLA.0000000000001029
53. Myles PS, Devereaux PJ. Pros and cons of composite endpoints in anesthesia trials. *Anesthesiology* 2010;113(4):776-8. doi: 10.1097/ALN.0b013e3181ee2ceb [published Online First: 2010/09/03]

54. Ferreira-Gonzalez I, Permanyer-Miralda G, Busse JW, et al. Composite outcomes can distort the nature and magnitude of treatment benefits in clinical trials. *Ann Intern Med* 2009;150(8):566-7. doi: 150/8/566-b [pii] [published Online First: 2009/04/22]
55. Pogue J, Thabane L, Devereaux PJ, et al. Testing for heterogeneity among the components of a binary composite outcome in a clinical trial. *BMC Med Res Methodol* 2010;10:49. doi: 10.1186/1471-2288-10-49
56. Khuri SF, Henderson WG, DePalma RG, et al. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242(3):326-41; discussion 41-3. doi: 00000658-200509000-00004 [pii] [published Online First: 2005/09/02]
57. Myles PS, Peyton P, Silbert B, et al. Perioperative epidural analgesia for major abdominal surgery for cancer and recurrence-free survival: randomised trial. *BMJ* 2011;342:d1491. doi: 10.1136/bmj.d1491

bmj.d1491 [pii] [published Online First: 2011/03/31]
58. Sheingold SH, Zuckerman R, Shartzer A. Understanding Medicare Hospital Readmission Rates And Differing Penalties Between Safety-Net And Other Hospitals. *Health Aff (Millwood)* 2016;35(1):124-31. doi: 10.1377/hlthaff.2015.0534

Legend

Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

Table 1. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Types of Surgery.

Surgery	No. of patients	No. admitted to a rehabilitation hospital (%)	Median (95% CI) DAH_{30}†
Cardiac	679	54 (8.0)	22.8 (22.6-22.9)
Orthopaedic	289	122 (42)	21.9 (21.2-22.6)
Neurosurgery	220	9 (4.0)	22.8 (22.2-23.5)
Colorectal	118	8 (6.8)	24.9 (23.9-26.0)
Urology	315	26 (8.3)	23.8 (23.0-24.5)
Vascular	56	1 (1.8)	26.0 (24.3-27.3)
Ear, nose, throat	99	17 (17)	25.8 (24.9-27.0)
Oesophagogastric/hepatobiliary	253	4 (1.6)	24.9 (23.8-26.1)
Thoracic	28	2 (7.1)	22.8 (17.8-27.8)
Other	52	2 (3.8)	28.8 (27.7-30.0)

† hospital days do not include those spent in a rehabilitation facility

Table 2. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw median DAH_{30} (95% CI)	P value	Adjusted median DAH_{30} (95% CI)†	P-value
Patient age			<0.001		<0.001
<50 years	220 (11)	24.9 (24.4 - 25.4)		24.8 (24.4 - 25.2)	
50-60 years	396 (19)	24.0 (23.4 - 24.6)		24.4 (24.0 - 24.9)	
60-70 years	612 (29)	23.9 (23.8 - 24.0)		24.0 (23.6 - 24.3)	
70-80 years	653 (31)	22.8 (22.6 - 23.0)		23.0 (22.7 - 23.4)	
≥80 years	228 (11)	22.7 (22.0 - 23.5)		22.2 (21.7 - 22.7)	
Sex			0.042		0.14
Male	1427 (68)	23.7 (23.1 - 24.2)		23.7 (23.5 - 24.0)	
Female	682 (32)	24.0 (23.7 - 24.2)		23.5 (23.2 - 23.8)	
Smoker			0.094		
yes	787 (37)	23.2 (22.6 - 23.8)		not done	
no	1322 (63)	23.8 (23.7 - 23.9)		not done	
Diabetes			0.003		
yes	697 (33)	23.0 (22.4 - 23.6)		not done	
no	1412 (67)	23.8 (23.8 - 23. 9)		not done	
Heart failure					
yes	365 (17)	22.9 (22.4 - 23.4)	0.002	not done	
no	1744 (83)	23.8 (23.7 - 23.9)		not done	
ASA physical status					<0.001
1	41 (1.9)	28.0 (26.3 - 29.7)	<0.001	25.9 (25.1 - 26.6)	
2	530 (25)	25.0 (24.7 - 25.3)		24.4 (24.0 - 24.7)	
3	1024 (51)	23.7 (23.1 - 24.3)		23.6 (23.2 - 23.9)	
4	510 (24)	22.0 (21.4 - 22.5)		23.0 (22.6 - 23.3)	
Duration of Surgery, h			<0.001		<0.001
<2.0	581 (29)	25.9 (25.7 - 26.1)		25.6 (25.2 - 26.0)	
2.0-2.99	412 (20)	24.0 (23.5 - 24.5)		24.0 (23.7 - 24.3)	
3.0-3.99	551 (26)	22.9 (22.8 - 23.1)		23.1 (22.7 - 23.4)	
≥4.0	565 (27)	21.9 (21.4 - 22.3)		22.0 (21.6 - 22.5)	

†covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table 3. Median (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value†
Myocardial infarction (120 [6.5])	1846	20.8 (19.2 - 22.4)	23.8 (23.7 - 23.9)	<0.001
Stroke (13 [0.7])	1846	10.1 (2.5 - 17.7)	23.8 (23.5 - 24.0)	<0.001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.4 - 25.9)	23.7 (23.5 - 24.0)	0.012
Cardiac arrest (3 [0.2])	1846	17.7 (0.9 - 34.5)	23.7 (23.5 - 24.0)	0.018
Surgical site infection (129 [7.0])	1846	21.0 (19.0 - 23.0)	23.8 (23.7 - 23.9)	<0.001
Any of the above (263 [14.2])	1846	20.5 (19.1 - 21.9)	23.9 (23.8 - 23.9)	<0.001
Hospital readmission (150 [7.1])	2090	17.9 (16.3 - 19.5)	23.9 (23.8 - 23.9)	<0.001

† P values calculated using the quasi- likelihood ratio test.

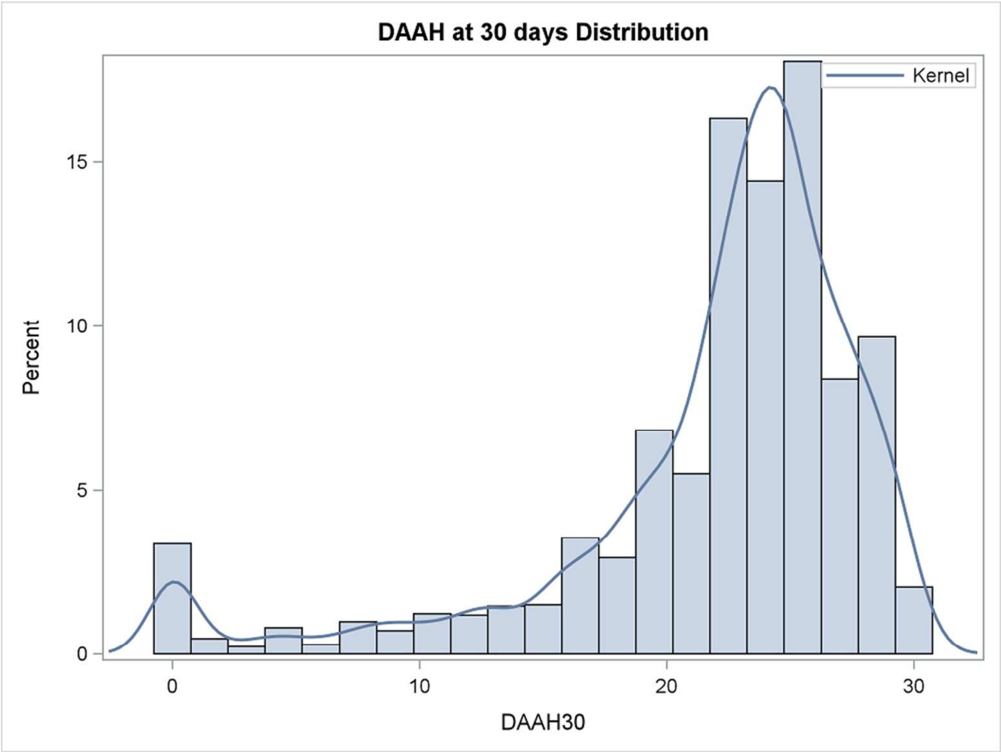


Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

84x63mm (300 x 300 DPI)

Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Days Alive and at Home after Surgery

Proposed Method of Calculation of "Days at Home within 30 days of Surgery" (DAH_{30})

DAH_{30} is a composite measure incorporating hospital length of stay in the hospital following the index surgery, re-admission to either the index or any other hospital, and including post-acute hospital discharge to a rehabilitation centre/hospital or other nursing facility, and early deaths after surgery, into a single outcome metric.

DAH_{30} is a numerical outcome measure that provides greater statistical power to detect clinically important differences in outcome. It is likely that a 0.5 day difference would be clinically important and valued by most people. A hospital bed day has been costed at £400 by the NHS in the UK, and $1800 in the US. It has the potential to increase the available hospital beds by about 8%.

By its very nature, DAH_{30} will be left-skewed with a spike at 0 (reflecting in-hospital deaths and those still admitted to hospital or other nursing facility at 30 days after surgery).

DAH_{30} is calculated using mortality and hospitalisation data from the date of the index surgery (= Day 0). For example, if a patient died on day 2 after their surgery whilst still an inpatient, they would be assigned 0 $DAH_{30;}$ if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they would be assigned 20 DAH_{30}. If a patient has complications and spends 16 days in hospital, and then is transferred to a nursing facility for rehabilitation, and spend 24 days there before finally being discharged to their own home, they would be assigned 0 DAH_{30}. (30-16-24 = -10, but the minimum value of DAH_{30} should be zero*).

Patients having a planned re-admission (eg. removal of a stent or secondary closure of a fistula) within 30 days of surgery should have these days subtracted from the total DAH_{30}. That is, if a patient is discharged from hospital on Day 13, and is electively re-admitted two weeks later (Day 27) for a further 2 days, their DAH_{30} will be calculated as 30-13-2 (=15).

Important: If a patient dies within 30 days of surgery, irrespective of whether they have spent some time at home, DAH_{30} should be scored as zero (0).

***an alternative would be to use DAH_{90} (up to 90 days after surgery) as an outcome metric in circumstances where a longer postoperative recovery is expected.

Table S1. Trial Data Sources

Trial	N	Reference
1. Tranexamic acid in coronary artery surgery	613	N Engl J Med 2016; Oct
2. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial	516	Lancet 2014; 384:1446-54.
3. An enhanced recovery after surgery (ERAS) program for hip and knee arthroplasty	310	Med J Aust 2015; 202:363-8.
4. Experience of an enhanced recovery after surgery (ERAS) program for elective abdominal surgery	71	Anaesth Intensive Care 2012; 40:450-9.
5. The measurement of disability-free survival after surgery	163	Anesthesiology 2015; 122:524-36.
6. Perioperative management of patients treated with angiotensin converting enzyme inhibitors and angiotensin II receptor blockers: a quality improvement audit	263	Anaesth Intensive Care 2016; 44:346-52.
7. Restrictive versus liberal fluid therapy in major abdominal surgery	173	ClinicalTrials.gov NCT01424150

Figure S1. The impact of the quantile (50^{th} – 75^{th} percentile) choice for days at home up to 30 days (here, DAAH30) on the associations of patient age category, ASA physical status and surgical duration, demonstrating the covariates are reasonably stable over this range.

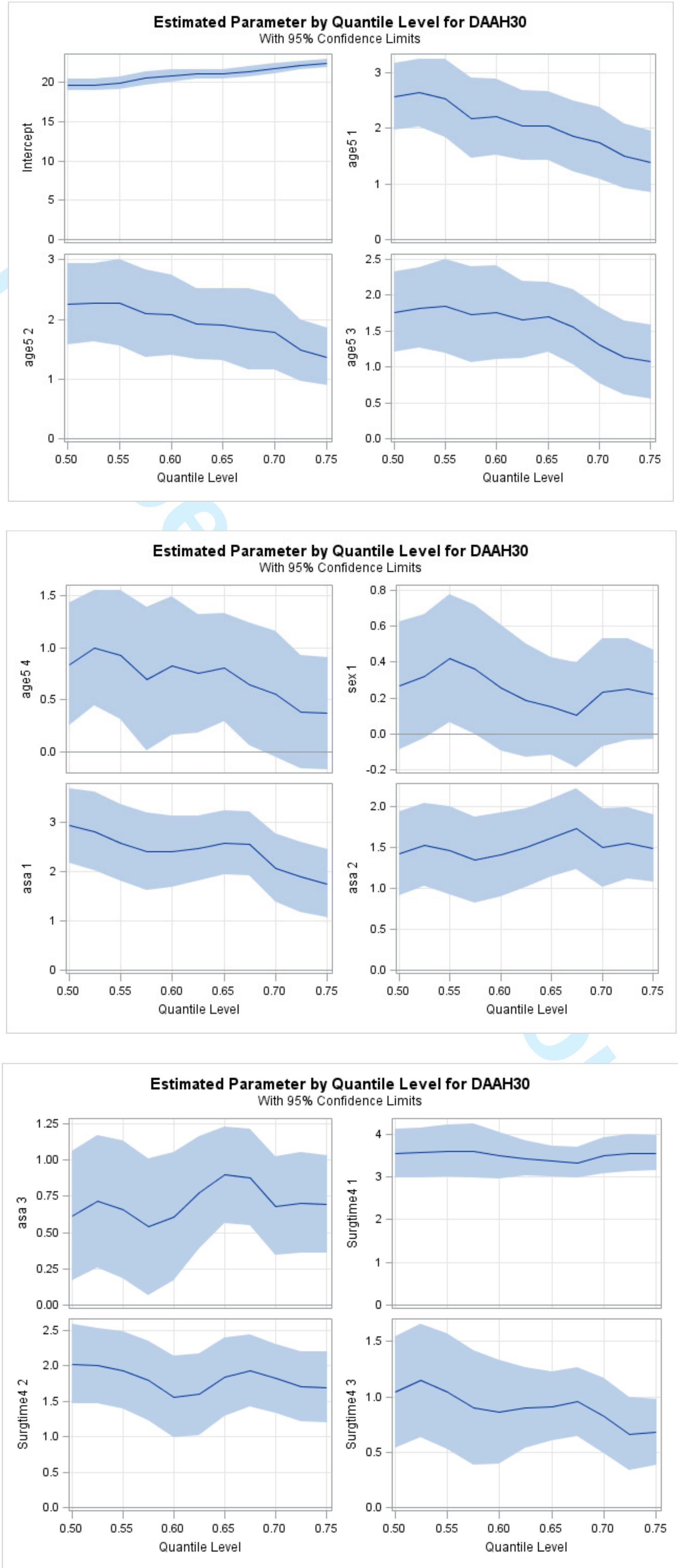


Table S2. Third Quartile (Q3) Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw Q3 DAH_{30} (95% CI)	P value	Adjusted Q3 DAH_{30} (95% CI)*	P-value
Patient age					
<50 years	220 (11)	27.2 (26.5 , 27.9)	<.0001	26.1 (25.8 , 26.5)	<0.0001
50-60 years	396 (19)	25.9 (25.5 , 26.4)		26.1 (25.9 , 26.4)	
60-70 years	612 (29)	25.7 (25.0 , 26.4)		25.8 (25.6 , 26.1)	
70-80 years	653 (31)	25.0 (24.6 , 25.4)		25.1 (24.8 , 25.4)	
≥80 years	228 (11)	24.8 (24.3 , 25.3)		24.7 (24.1 , 25.4)	
Sex					
Male	1427 (68)	25.1 (24.8 , 25.4)	<.0001	25.6 (25.5 , 25.8)	0.146
Female	682 (32)	26.2 (25.6 , 26.8)		25.4 (25.2 , 25.7)	
Smoker					
yes	787 (37)	25.0 (24.8 , 25.1)	<.0001	not done	
no	1322 (63)	26.0 (25.7 , 26.2)		not done	
Diabetes					
yes	697 (33)	25.8 (25.1 , 26.5)	>.99	not done	
no	1412 (67)	25.8 (25.6 , 26.0)		not done	
Heart failure					
yes	365 (17)	25.9 (25.2 , 26.7)	0.39	not done	
no	1744 (83)	25.8 (25.4 , 26.2)		not done	
ASA physical status					
1	41 (1.9)	29.0 (28.8 , 29.3)	<.0001	26.6 (26.0 , 27.2)	<0.0001
2	530 (25)	27.0 (26.9 , 27.1)		26.3 (26.0 , 26.6)	
3	1024 (51)	25.8 (25.3 , 26.3)		25.5 (25.3 , 25.8)	
4	510 (24)	23.9 (23.8 , 24.0)		24.8 (24.5 , 25.1)	
Duration of Surgery, h					
<2.0	581 (29)	28.1 (27.7 , 28.6)	<.0001	27.6 (27.3 , 28.0)	<0.0001
2.0-2.99	412 (20)	26.1 (25.6 , 26.5)		25.8 (25.4 , 26.2)	
3.0-3.99	551 (26)	24.8 (24.7 , 24.9)		24.8 (24.5 , 25.0)	
≥4.0	565 (27)	23.9 (23.8 , 23.9)		24.1 (23.8 , 24.4)	

The effect of the different covariates were largely consistent across a large range of meaningful percentile values (e.g. 50^{th} – 75^{th}) with a slightly smaller effect for age categories as the percentile gets higher but for simplicity we only present the results for Q3 (75^{th} percentile). This percentile is also close to the main mode of the distribution.

*****covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table S3. Third Quartile (Q3) (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	22.9 (22.2 - 23.5)	25.8 (25.4 - 26.2)	<0.0001
Stroke (13 [0.7])	1846	18.9 (10.0 - 27.8)	25.2 (24.6 - 25.7)	0.019
Pulmonary embolism (7 [0.4])	1846	23.1 (16.1 - 30.1)	25.2 (24.6 - 25.7)	0.19
Cardiac arrest (3 [0.2])	1846	20.1 (8.0 - 32.1)	25.2 (24.6 - 25.7)	0.052
Surgical site infection (129 [7.0])	1846	24.8 (23.7 - 26.0)	25.3 (24.7 - 25.9)	<0.0001
Any of the above (263 [14.2])	1846	23.7 (23.0 - 24.5)	25.8 (25.6 - 26.1)	<0.0001
Hospital readmission (150 [7.1])	2090	21.7 (20.8 - 22.7)	25.9 (25.8 - 26.0)	<0.0001

[a] P values calculated using likelihood ratio test.

Table S4. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.

Surgery	No. admitted to a rehabilitation hospital (%)	Mean (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.7-22.9)
Orthopaedic (n=289)	122 (42)	21.9 (21.2-22.6)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (24.1-25.8)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.9-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

Table S5. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.∞

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value#
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.5 - 25.2)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.5 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.2 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.4 (20.4 - 22.4)	
Sex			0.90		0.0052
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.4 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			>0.99		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.6 - 23.4)			
Diabetes			0.091		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.6 - 23.8)			
Heart failure			0.16		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status					
1	41 (1.9)	27.9 (26.1 - 29.7)		25.3 (24.3 - 26.3)	<0.0001
2	530 (25)	24.9 (24.6 - 25.1)	<0.0001	24.0 (23.6 - 24.5)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.3)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.3)		23.6 (23.2 - 24.0)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

#P values calculated using the quasi-likelihood ratio test.

∞ If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S6. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.*

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.6 - 21.5)	23.1 (22.6 - 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.7 - 16.5)	23.0 (22.8 - 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.0 - 26.3)	23.0 (22.7 - 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.7 - 29.4)	23.0 (22.8 - 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (18.9 - 22.6)	23.1 (22.6 - 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 - 20.8)	23.7 (23.3 - 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 - 19.0)	23.7 (23.3 - 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.
[b] days calculated for those without readmission after excluding postoperative deaths.

* If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S7. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.*

Surgery	No. admitted to a rehabilitation hospital (%)	Median (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.6-22.9)
Orthopedic (n=289)	122 (42)	20.9 (17.5-24.4)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (23.9-26.0)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.8-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

*If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S8. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.4 - 25.3)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.6 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.3 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.5 (20.5 , 22.4)	
Sex			0.84		0.0065
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.3 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			0.92		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.5 - 23.4)			
Diabetes			0.12		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.5 - 23.8)			
Heart failure			0.19		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status			<0.0001		<0.0001
1	41 (1.9)	27.9 (26.0 - 29.8)		25.3 (24.2 - 26.3)	
2	530 (25)	24.9 (24.6 - 25.1)		24.1 (23.6 - 24.6)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.4)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.4)		23.6 (23.2 - 24.1)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery.
#If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S9. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.5 , 21.6)	23.1 (22.6 , 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.4 , 16.9)	23.0 (22.8 , 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.3 , 26.0)	23.0 (22.7 , 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.4 , 29.8)	23.0 (22.8 , 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (19.0 , 22.5)	23.1 (22.6 , 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 , 20.8)	23.7 (23.3 , 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 , 18.9)	23.7 (23.3 , 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.

[b] Days calculated for those without readmission after excluding postoperative deaths. If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4,5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	n/a
		(*e*) Describe any sensitivity analyses	10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Not used
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Table 2
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	Report numbers of outcome events or summary measures over time	10,22
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12,14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Validation of Days at Home as an Outcome Measure after Surgery: a propesctive cohort study in Australia

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-015828.R3
Article Type:	Research
Date Submitted by the Author:	14-Jun-2017
Complete List of Authors:	Myles, Paul; Alfred Hospital and Monash University, Anaesthesia and Perioperative Medicine Shulman, Mark; Alfred Hospital Heritier, Stephane; School of Public Health and Preventive Medicine, Monash University, Department of Epidemiology and Preventive Medicine Wallace, Sophie; Alfred Hospital McIlroy, David; Alfred Hospital, Department of Anaesthesia and Perioperative Medicine McCluskey, Stuart; University Health Network, Anesthesia and Pain Medicine Sillar, Isabella; Alfred Hospital Forbes, Andrew; Monash University
Primary Subject Heading:	Anaesthesia
Secondary Subject Heading:	Surgery, Epidemiology
Keywords:	STATISTICS & RESEARCH METHODS, outcome, perioperative medicine, Clinical trials < THERAPEUTICS

Validation of Days at Home as an Outcome Measure after Surgery: a prospective cohort study in Australia

Paul S. Myles,[1,2,3] Mark A. Shulman,[1] Stephane Heritier,[3] Sophie Wallace,[1] David R. McIlroy,[1,2] Stuart McCluskey,[4] Isabella Sillar,[2] Andrew Forbes[3]

[1]Department of Anaesthesia and Perioperative Medicine, Alfred Hospital, Melbourne, Australia
[2]Department of Anaesthesia and Perioperative Medicine, Monash University, Melbourne, Australia
[3]Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, Australia
[4]Toronto General Hospital and University of Toronto, Toronto, ON, Canada

ADDRESS FOR CORRESPONDENCE
Paul S. Myles
Professor and Chair
Department of Anaesthesia and Perioperative Medicine
Alfred Hospital, Commercial Road, Melbourne, Victoria, 3004, Australia

Email: p.myles@alfred.org.au

Word count: 3035

Competing interest statement - All authors declare that the answer to the questions on the competing interest form are all No and therefore have nothing to declare.

Funding - The Australian and New Zealand College of Anaesthetists; and the Australian National Health and Medical Research Council Practitioner Fellowship (Prof Myles).

ABSTRACT

OBJECTIVE To evaluate "days at home up to 30 days after surgery" (DAH_{30}) as a patient-centred outcome measure.

DESIGN Prospective cohort study.

DATA SOURCE Using clinical trial data (7 trials, 2109 patients) we calculated DAH_{30} from length of stay, re-admission, discharge destination, and death up to 30 days after surgery.

MAIN OUTCOME The association between DAH_{30} and serious complications after surgery.

RESULTS One or more complications occurred in 263 of 1846 (14.2%) patients, including 19 (1.0%) deaths within 30 days of surgery; 245 (11.6%) patients were discharged to a rehabilitation facility and 150 (7.1%) were readmitted to hospital within 30 days of surgery. The median DAH_{30} was significantly less in older patients (P<0.001), those with poorer physical functioning (P<0.001), and in those undergoing longer operations (P<0.001). Patients with serious complications had less days at home than patients without serious complications (20.5 [95% CI, 19.1 to 21.9] vs 23.9 [95% CI, 23.8 to 23.9] P<0 .001), and had higher rates of readmission (16.0% vs. 5.9%; P < 0.001). After adjusting for patient age, sex, physical status and duration of surgery, the occurrence of postoperative complications was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.001).

CONCLUSIONS DAH_{30} has construct validity and is a readily-obtainable generic patient-centred outcome measure. It is a pragmatic outcome measure for perioperative clinical trials.

Strengths and limitations of the study

- This study integrates length of stay, re-admission, discharge destination, and early deaths after surgery into a single outcome metric, "days at home up to 30 days after surgery" (DAH_{30})
- Patients hope to recover quickly after surgery, free of complications and need for re-admission; DAH_{30} is thus a patient-centred outcome
- Accurate calculation of DAH_{30} requires knowledge of post-discharge location (home or nursing facility) and any re-admissions at the index or other hospitals
- Because early deaths heavily influence the DAH_{30} metric, this information should be additionally reported if, say, the incidence exceeds 10%

Introduction

Surgery and other interventional procedures are intended to relieve symptoms and in many cases prolong life. But surgery is not risk-free; perioperative complications can impair patient recovery resulting in prolonged hospitalization, short or longer term disability, and sometimes poor survival. A wide variety of outcome measures have been used to quantify each of these aspects of the postoperative experience but few provide a broad, patient-centred perspective of effective and efficient care;[1] these are needed to better inform the current shift towards value-based healthcare.[2 3]

Patient-centred care requires clinicians to consider outcomes that matter most to patients. That is, the patient's experience of their illness, quality of life, and functioning; their values, preferences and goals for health care.[4] Loss of the ability to live independently is a major concern for the elderly;[5 6] it is clearly a patient-centred outcome, and has been associated with postoperative readmissions and death after hospital discharge.[5]

Specific peri-procedural complications such as surgical site infection, respiratory failure, delirium, and myocardial infarction are clearly important to patients and physicians alike, but reliable and consistent detection is problematic. In any case such information is an incomplete description of the overall success of surgery and other perioperative care, and does not describe the impact of such complications on functioning and need for institutionalization. Similar challenges occur when nominating endpoints in clinical trials, including a lack of standardisation,[7] need for adjudication, and uncertainty about the overall health impact of each endpoint on a patient's recovery. There is a growing acceptance that

outcome measures used in clinical trials should be determined in partnership by patients and physician-researchers, aiming to identify outcomes that are important to patients.[8]

"Days alive and out of hospital" has been shown to be a readily quantifiable and patient-centred outcome measure in some chronic cardiovascular conditions such as heart failure and atrial fibrillation,[9-11] and in geriatric medicine,[12] but it has not been used as an outcome measure in perioperative trials. Home discharge has been proposed as a proxy for a patient's recovery after surgery,[13] and is estimated when using the American College of Surgeons' Surgical Risk Calculator,[14] but this does not account for readmissions or early deaths, although the latter collects and reports some of this information.[15]

Our own work and that of others have shown that early return home after surgery,[6 16-18] and medical illnesses such as stroke,[19 20] is highly valued by patients but could be undermined if the patient were to be transferred to another type of nursing facility. A more favourable perioperative outcome measure should account for both the initial hospital stay associated with the index surgery, rehospitalisation due to post-discharge complications, discharge to institutional care, and early deaths.

We thus chose to evaluate the utility of "days (alive and) at home" within 30 days of surgery (DAH_{30}) in the surgical/perioperative setting as a patient-centred outcome measure for perioperative clinical trials and quality improvement activities. Our hypothesis was that DAH_{30} would be lower in higher risk patients, those undergoing more extensive surgery, and in those with complications after surgery (i.e. it has construct validity).

Methods

This manuscript was written in adherence to the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) statement.[21]

Study Design and Data Sources

Data were obtained from each of seven recently completed clinical trials that prospectively enrolled patients undergoing various types of elective and emergency surgery at the Alfred Hospital in Melbourne, Australia. The cohort consisted of four multicentre randomised trials and three before-and-after studies (see Table S1 in the Supplementary Appendix).[22-29] For each trial we collected a comparable set of patient demographic and perioperative characteristics, and clinical outcome measures, including complete hospital discharge, discharge destination (home, rehabilitation facility, nursing home) and re-admission data. All but one study[28] prospectively recorded re-admission data; for the latter study we could obtain this information retrospectively from our hospital information system. Both the present study and each of the original trials received institutional ethics committee approval.

Patients

Patients 18 years and older undergoing an elective or non-elective inpatient operation enrolled in one of the aforementioned trials were included. Study inclusion criteria were established for the original studies and typically identified those at increased risk of postoperative complications. In all cases patients provided informed consent before enrolment in the original trials.

Patient involvement

Hospital patients have previously indicated the importance of returning home after hospitalisation for medical or surgical conditions, [6 16-20] but we did not involve patients or their carers in the design or conduct of this study.

Risk Factors and Outcomes

Perioperative data included patient demographics, comorbidity, functional status, type and duration of surgery, hospital length of stay, hospital readmission(s), and in all but one study[28] we prospectively collected selected complications at 30 days after surgery: wound infection, myocardial infarction, stroke, pulmonary embolism, cardiac arrest, and death.

Hospital discharge data were used to calculate hospital length of stay. Whether the patient was discharged from hospital to their home or to a nursing facility was obtained from the electronic medical record, but for those admitted to a rehabilitation facility we were unable to ascertain the number of days admitted before eventual discharge home. For those readmitted to hospital we combined the original length of stay with subsequent hospital stay(s) to calculate total length of stay within 30 days postoperatively.

DAH_{30} was calculated using mortality and hospitalisation data from the date of the index surgery (Day 0). For example, if a patient died on day 2 after their surgery, they were assigned 0 DAH_{30}, if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they were assigned 20 DAH_{30}. If a patient died within 30 days of surgery, irrespective of whether they

had spent some time at home, DAH_{30} was scored as zero (0). Further explanation is provided in the Supplementary Appendix.

Patients are commonly admitted to a post-acute hospital rehabilitation centre after lower limb arthroplasty and cardiac surgery in our setting; some frail and elderly patients are also transferred for ongoing convalescence. We were unable to reliably collect secondary length of stay for rehabilitation facilities - we thus did two secondary analysis, assuming the length of stay in a rehabilitation facility was 5 or 14 extra days. That is, $DAH_{30\text{-rehab5}}$ was calculated as DAH_{30}-5, and $DAH_{30\text{-rehab14}}$ was calculated as DAH_{30}-14, in secondary analyses.

For the multicentre trials,[22-24] a 12-lead electrocardiograph was recorded preoperatively and on day 1 and 3 after surgery. Blood for troponin (or if unavailable, creatine kinase-myocardial band) measurement was collected at 6 to 12 hours after surgery and on the first three postoperative days. In all trials laboratory tests were otherwise ordered if clinically indicated. Each complication was defined within the original study protocol and in all cases a consistent definition was used. In brief, surgical site infection was confirmed if associated with purulent discharge, with or without a positive microbial culture; or pathogenic organisms isolated from aseptically obtained microbial culture,[30] although the most recent trial[27] included documentation of a physician's diagnosis in this definition.[31] Pneumonia was confirmed by a new pulmonary infiltrate reported by chest x-ray or computerized tomography, in association with at least one of: temperature >38°C, white cell count >12,000/ml, or positive sputum culture that was not heavily contaminated with oral flora or that corresponded with positive blood cultures. Myocardial infarction was defined according to the third universal definition,[32] requiring elevated cardiac biomarker plus at least one of the

following: (i) ischaemic symptoms, (ii) pathological Q waves, (iii) electrocardiographic changes indicative of ischemia, (iv) coronary artery intervention or (v) new wall motion abnormality on echocardiography or scanning; or autopsy finding of myocardial infarction. The threshold for significant elevated troponin was the hospital laboratory's 99th percentile of a normal reference population (upper reference limit), according to recent recommendations.[33] Stroke was confirmed if a new neurological deficit persisting for at least 24 hours, verified by neurologist assessment and/or computerized tomography or magnetic resonance imaging.

Statistical Analysis[34 35]

Data were first merged and checked for inconsistencies. Patient age was grouped into 10-year categories, and hourly cut-points for duration of surgery (2, 3, and 4 h) were created to generate approximately similar group sizes and facilitate clinical interpretation. DAH_{30} was analysed using quantile regression.[36] This approach, well known in econometrics where it was initially introduced, allows the modelling of any quantile of a continuous endpoint, here DAH_{30}, as a linear combination of the covariates. As DAH_{30} is left skewed with a spike at zero, it is more relevant to model the median (or alternatively, the 75^{th} percentile) that is closer to the major distribution mode and directly interpretable. The choice of the quantile(s) to be analysed can be prespecified or a range of values selected for their meaningfulness or exploratory purposes. Here the range 50^{th}-75^{th} percentile was deemed relevant. No assumption on the true distribution of the endpoint is required. The asymptotic distribution of the parameter estimates can be derived but depends on some unknown density estimate. In general, resampling methods are recommended to obtain confidence intervals (CIs).[37 38] Raw and adjusted medians and their 95% CIs obtained by bootstrapping as implemented in Stata with 1000 replicates were reported for key predictors. The adjusted models included age by 10-year categories, sex, American Society of Anesthesiologists (ASA) physical status score, surgery time (< 2h, 2.0 - 2.99, 3.0 -3.99, ≥4.0). A goodness of fit test[39] comparing this model to the full model including the same predictors plus smoking, heart failure and diabetes was not any better (P=0.36). A global test of effect of any key predictor was carried out using a quasi-likelihood ratio test.[39] Quantile regression was also used to test median differences between those with and without complications, and by postoperative complications. Supplementary analyses were done for the 75th percentile (Q3). All analyses were done using Stata 14.0 except the quasi-likelihood ratio test analysis that is only available in SAS. All tests were two-sided and performed at level ⍰=0.05; no correction was made for multiple comparisons.

Results

A total of 2109 eligible patients 18 years and older were enrolled into clinical trials and underwent inpatient operations at the Alfred Hospital between March 2006 and September 2016. The number of patients enrolled in each of the trials is detailed in the Supplement (Supplementary Table 1). The cohort included 1427 male patients (67.7%) with a mean (SD) age of 65 (12) years who underwent a range of inpatient operations (Table 1). Most operations were cardiac surgical procedures (679 [32.2%]), followed by general (489 [23.2%]), urologic (315 [14.9%]), and neurosurgical procedures (220 [10.4%]).

There was a bimodal, skewed distribution of DAH_{30} (Figure 1). The spike at zero consisted of 19 patients (1.0%) that died, and 40 patients remaining in hospital at least 30 days after

surgery. DAH_{30} and rates of admission to a rehabilitation centre varied according to type of surgery (Table 2).

One or more complications occurred in 263 (14.2%) patients. Overall, 245 (11.6%) patients were admitted to a rehabilitation facility and 150 (7.1%) were readmitted within 30 days of surgery. The median DAH_{30} was 23.7 (95% CI, 23.5 to 24.0), but this varied according to type of surgery (Table 1).

The median DAH_{30} was significantly less in older patients, current smokers, diabetics, those with poorer physical functioning, and undergoing longer operations (Table 2). These associations remained after adjustment for all of these covariates and patient sex (Table 2). The individual complications of myocardial infarction, stroke, pulmonary embolism, and surgical site infection were each associated with shorter DAH_{30} (Table 3) in a raw analysis. Hospital readmission was also a factor, decreasing median DAH_{30} when compared with those not readmitted to hospital, 17.9 (95% CI, 16.3 to 19.5) vs 23.9 (95% CI, 23.8 to 23.9), respectively (P<0.0001).

After adjusting for patient age, sex, ASA physical status and duration of surgery, the occurrence of any postoperative complication was associated with fewer days at home after surgery (difference 3.0 [95% CI, 2.1 to 4.0] days; P<0.0001).

Supplementary Analyses

The above findings were consistent when analysing the 3rd quartile distributions and differences (Tables S2-S4 in the Supplementary Appendix), and after accounting for the additional loss of days at home because of admission to a rehabilitation centre (Tables S5 – S9 in the Supplementary Appendix).

Discussion

We found that DAH_{30} has construct validity and is a readily-obtainable patient-centred outcome measure that could be used to better inform patients and physicians when planning surgery. Unlike previous related measures, DAH_{30} accounts for each of delayed hospital discharge because of postoperative complications, discharge to a rehabilitation centre or other post-acute care nursing facility, rehospitalisations, and postoperative deaths. It thus captures much of the surgical experience, integrating efficacy, quality and safety, and thus reflecting value-based care. It can also be risk-adjusted for bench-marking purposes. DAH_{30} will be maximized when patients recover free of complications after surgery, with optimal comfort and functioning - aligning with patient values and preferences, and goals for health care.[4]

Although concerns are frequently raised about the usefulness of hospital length of stay as an outcome measure after surgery, largely because of social factors and reluctance to discharge on weekends, it mostly adds variance (background noise) in clinical trials and is not biased. Hospital stay is a reasonable surrogate for quality and speed of recovery after surgery,[13 40-42] and it has marked resource/cost implications. Most patients want to go home as soon as possible – it is a desired outcome in and of itself.

The US has a triple aim of improving the healthcare system: improving the patient experience of care, improving the health of populations, and reducing per capita costs of healthcare.[43] DAH_{30} seems to be useful, generic metric in this regard.[44] DAH_{30} is a measure of the overall burden of care, both in hospital and post-discharge. The perceived success of a hospital discharge plan as perceived by the patient and their principal carer depends on clear communication and meeting expectations.[45] DAH_{30} offers transparency and opportunities for benchmarking performance, both of which are important components of quality improvement.[1 3] It may influence alternative payment contracts for hospitals.

Postoperative complications add to hospital costs and increase length of stay.[46] Higher episode payments at “lower-quality” hospitals have been attributed to higher rates of complications, 30-day readmissions, and post-discharge ancillary care.[46] Serious postoperative complications are both strongly associated with readmission,[5 17] increasing the risk by 6.7-fold, and loss of independence.[5] Readmission is a frequent, costly, and sometimes life-threatening event that is associated with gaps in follow-up care.[15 17 47] Readmission after surgery is thus an established quality indicator. Trends in readmissions suggest that US hospitals are responding to incentives to reduce readmissions under the Affordable Care Act.[48 49] Hospital readmission rates are not highly correlated with mortality rates, [50] so they offer an independent and more sensitive measure of quality. Even though some readmissions are due to chronic medical conditions,[47] optimal perioperative care should keep these to a minimum and such improvements should be reflected in more DAH_{30}.

Enhanced recovery after surgery programs are designed to reduce complications and shorten length of stay. But this sometimes comes at the cost of increased hospital re-admissions.[51 52] The measurement and reporting of DAH_{30} would identify this and hopefully encourage further quality improvement. Planned discharge to a rehabilitation facility sometimes forms part of an enhanced recovery pathway, and in any case may not be seen by the patient or their family as indicating a poor outcome. Therefore, calculation of DAH_{30} in some studies could incorporate days spent in a rehabilitation facility as equivalent to being home. In contrast, unplanned admission to a rehabilitation facility would indicate poor care or adverse outcome, and this should be retained in the calculation of DAH_{30}. Care should be taken to avoid missing out-of-network hospitalizations, particularly if relying on hospital system electronic medical records. The latter will otherwise enhance the efficiency of data collection.

Composite endpoints used in perioperative trials are often flawed,[53-55] typically used to increase the number of events in order to enhance statistical power. DAH_{30}, as a numerical patient-centred measure, provides more statistical power, can be reliably measured and has direct patient-centredness. Although some postoperative complications and poor survival can manifest many months after surgery in those recovering from major surgery or critical illness,[29 56 57] extending measurement out to 90 days after surgery (i.e. DAH_{90}) may not necessarily provide new or different information because the extra burden and costs of further data collection may outweigh the benefits of the extra information obtained. In addition, disease progression or other aspects of life may confound outcome evaluation of perioperative care.

Our study has several limitations. First, this was a single-centre study of clinical trial data collected for other purposes; external validity needs to be further evaluated. Second, postoperative in-hospital deaths have a major influence on the calculation of DAH_{30}; this is arguably appropriate because perioperative studies should weight this as the most extreme adverse outcome. More sophisticated modelling could jointly model the risk of death and DAH_{30} in those discharged alive, and such modelling would be particularly important if the in-hospital mortality rate is moderate or greater. Third, different health care settings can be expected to have varied casemix and hospital discharge processes, and hospital discharge may be delayed because of social and process issues unrelated to complications or quality of care. DAH_{30} should therefore be risk-adjusted.[58] Fourth, DAH_{30} doesn't provide specific information on which aspects of in-hospital or post-discharge management influences where patients reside after hospitalization, or the post-discharge use and effectiveness of family physician or other health care resources. Fifth, DAH_{30} is an overall measure of recovery profile and does not inform us about specific complications, level of functioning or wellbeing. Such aspects should also be included when conducting outcome studies. Sixth, obtaining accurate data on days spent in a rehabilitation facility relies on further follow-up or accurate electronic records. Future studies using DAH_{30} should prospectively plan to reliably obtain such data.

CONCLUSIONS

DAH_{30} has construct validity and is a readily-obtainable, generic, patient-centred outcome measure that can better inform patients and physicians when planning surgery. It is a suitable outcome measure for both quality improvement and perioperative clinical trials. DAH_{30} accounts for prolonged hospital stay, discharge to any post-acute care nursing facility,

rehospitalizations, and early deaths. It thus captures much of the patient-centred experience, and will be maximal when effective and efficient care is achieved.

Contributor statement: PM designed the study, oversaw the ethics application, devised the statistical analysis plan, and drafted and revised the paper. He is guarantor. MS provided intellectual input into the study design, and drafted and revised the paper. SH analysed the data and drafted and revised the paper. SW prepared the ethics application, monitored the data entry and checking, and drafted and revised the paper. DM provided intellectual input into the study design, and drafted and revised the paper. SM provided intellectual input into the study design, and drafted and revised the paper. IS retrieved and entered all study data, and revised the paper. AF contributed to the statistical analysis, and drafted and revised the paper.

Transparency declaration: The lead author* affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

Acknowledgment: The authors would like to thank the study participants for their interest and preparedness to consent to the original trials. PM is supported in part by Practitioner Fellowships from the Australian National Health and Medical Research Council (NHMRC).

Funding: This work was supported by the Australian NHMRC, the New Zealand Health Research Council, and the Australian and New Zealand College of Anaesthetists, and Monash University (Melbourne, Australia).

Additional data: No additional data available.

Competing interests: None of the authors have any conflicts of interest

Ethics approval: This trial has been approved by the Ethics Committee of Alfred Health, Melbourne, Australia.

References

1. Austin JM, McGlynn EA, Pronovost PJ. Fostering Transparency in Outcomes, Quality, Safety, and Costs. *Jama* 2016 doi: 10.1001/jama.2016.14039 [published Online First: 2016/09/27]
2. Lynn J, McKethan A, Jha AK. Value-Based Payments Require Valuing What Matters to Patients. *JAMA* 2015;314(14):1445-6. doi: 10.1001/jama.2015.8909
3. Porter ME. What is value in health care? *N Engl J Med* 2010;363(26):2477-81. doi: 10.1056/NEJMp1011024 [published Online First: 2010/12/15]
4. Lavallee DC, Chenok KE, Love RM, et al. Incorporating Patient-Reported Outcomes Into Health Care To Engage Patients And Enhance Care. *Health Aff (Millwood)* 2016;35(4):575-82. doi: 10.1377/hlthaff.2015.1362 [published Online First: 2016/04/06]
5. Berian JR, Mohanty S, Ko CY, et al. Association of Loss of Independence With Readmission and Death After Discharge in Older Patients After Surgical Procedures. *JAMA Surg* 2016;151(9):e161689. doi: 10.1001/jamasurg.2016.1689 [published Online First: 2016/07/14]
6. Fried TR, Bradley EH, Towle VR, et al. Understanding the treatment preferences of seriously ill patients. *N Engl J Med* 2002;346(14):1061-6. doi: 10.1056/NEJMsa012528
7. Goldfarb M, Drudi L, Almohammadi M, et al. Outcome Reporting in Cardiac Surgery Trials: Systematic Review and Critical Appraisal. *J Am Heart Assoc* 2015;4(8):e002204. doi: 10.1161/jaha.115.002204 [published Online First: 2015/08/19]
8. Chalmers I, Clarke M. Outcomes that matter to patients in tombstone trials. *Lancet* 2001;358(9293):1649. doi: S0140673601066892 [pii] [published Online First: 2001/11/22]
9. Ariti CA, Cleland JG, Pocock SJ, et al. Days alive and out of hospital and the patient journey in patients with heart failure: Insights from the candesartan in heart failure: assessment of reduction in mortality and morbidity (CHARM) program. *Am Heart J* 2011;162(5):900-6. doi: 10.1016/j.ahj.2011.08.003
10. Wasywich CA, Gamble GD, Whalley GA, et al. Understanding changing patterns of survival and hospitalization for heart failure over two decades in New Zealand: utility of 'days alive and out of hospital' from epidemiological data. *Eur J Heart Fail* 2010;12(5):462-8. doi: 10.1093/eurjhf/hfq027
11. Xian Y, Wu J, O'Brien EC, et al. Real world effectiveness of warfarin among ischemic stroke patients with atrial fibrillation: observational analysis from Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research (PROSPER) study. *BMJ* 2015;351:h3786. doi: 10.1136/bmj.h3786
12. Ellis G, Whitehead MA, Robinson D, et al. Comprehensive geriatric assessment for older adults admitted to hospital: meta-analysis of randomised controlled trials. *Bmj* 2011;343:d6553. doi: 10.1136/bmj.d6553 [published Online First: 2011/10/29]
13. Hyder JA, Hirschberg RE, Nguyen LL. Home discharge as a performance metric for surgery. *JAMA Surg* 2015;150(2):96-7. doi: 10.1001/jamasurg.2014.1725 [published Online First: 2014/12/05]
14. Hyder JA, Wakeam E, Habermann EB, et al. Derivation and validation of a simple calculator to predict home discharge after surgery. *J Am Coll Surg* 2014;218(2):226-36. doi: 10.1016/j.jamcollsurg.2013.11.002
15. Merkow RP, Ju MH, Chung JW, et al. Underlying reasons associated with hospital readmission following surgery in the United States. *JAMA* 2015;313(5):483-95. doi: 10.1001/jama.2014.18614
16. Boney O, Bell M, Bell N, et al. Identifying research priorities in anaesthesia and perioperative care: final report of the joint National Institute of Academic Anaesthesia/James Lind Alliance Research Priority Setting Partnership. *BMJ Open* 2015;5(12):e010006. doi: 10.1136/bmjopen-2015-010006 [published Online First: 2015/12/18]
17. Hinami K, Bilimoria KY, Kallas PG, et al. Patient experiences after hospitalizations for elective surgery. *Am J Surg* 2014;207(6):855-62. doi: 10.1016/j.amjsurg.2013.04.014

18. Burns KE, Jacob SK, Aguirre V, et al. Stakeholder Engagement in Trial Design: Survey of Visitors to Critically Ill Patients Regarding Preferences for Outcomes and Treatment Options during Weaning from Mechanical Ventilation. *Ann Am Thorac Soc* 2016;13(11):1962-68. doi: 10.1513/AnnalsATS.201606-445OC [published Online First: 2016/09/07]
19. Hannah D, Lindholm B, Maisch L. Certain uncertainty: life after stroke from the patient's perspective. *Circ Cardiovasc Qual Outcomes* 2014;7(6):968-9. doi: 10.1161/CIRCOUTCOMES.114.001315
20. Xian Y, O'Brien EC, Fonarow GC, et al. Patient-Centered Research into Outcomes Stroke Patients Prefer and Effectiveness Research: Implementing the patient-driven research paradigm to aid decision making in stroke care. *Am Heart J* 2015;170(1):36-45, 45.e1-11. doi: 10.1016/j.ahj.2015.04.008 [published Online First: 2015/06/22]
21. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007;370(9596):1453-7. doi: 10.1016/S0140-6736(07)61602-X
22. Myles PS, Leslie K, Chan MT, et al. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial. *Lancet* 2014;384(9952):1446-54. doi: 10.1016/s0140-6736(14)60893-x [published Online First: 2014/08/22]
23. Myles PS, Smith JA, Forbes A, et al. Stopping vs. Continuing Aspirin before Coronary Artery Surgery. *N Engl J Med* 2016;374(8):728-37. doi: 10.1056/NEJMoa1507688
24. Myles PS, Smith JA, Forbes A, et al. Tranexamic acid in coronary artery surgery. *N Engl J Med* 2017;2017(376):136-48.
25. Thompson EG, Gower ST, Beilby DS, et al. Enhanced recovery after surgery program for elective abdominal surgery at three Victorian hospitals. *Anaesth Intensive Care* 2012;40(3):450-9. [published Online First: 2012/05/15]
26. Christelis N, Wallace S, Sage CE, et al. An enhanced recovery after surgery program for hip and knee arthroplasty. *Med J Aust* 2015;202(7):363-8.
27. Glassford NJ, Myles P, Bellomo R. The Australian approach to peri-operative fluid balance. *Curr Opin Anaesthesiol* 2012;25(1):102-10. doi: 10.1097/ACO.0b013e32834decd7 [published Online First: 2011/11/25]
28. Vijay A, Grover A, Coulson T, et al. Perioperative management of patients treated with angiotensin-converting enzyme inhibitors and angiotensin II receptor blockers. *Anaesth Intensive Care* 2016;in press
29. Shulman MA, Myles PS, Chan MT, et al. Measurement of disability-free survival after surgery. *Anesthesiology* 2015;122(3):524-36. doi: 10.1097/ALN.0000000000000586
30. Mangram A, Horan T, Pearson M, et al. Guideline for prevention of surgical site infection, 1999. *Infection Control and Hospital Epidemiology* 1999;20:247-77.
31. Degnim AC, Throckmorton AD, Boostrom SY, et al. Surgical site infection after breast surgery: impact of 2010 CDC reporting guidelines. *Ann Surg Oncol* 2012;19(13):4099-103. doi: 10.1245/s10434-012-2448-6
32. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Circulation* 2012;126(16):2020-35. doi: 10.1161/CIR.0b013e31826e1058

CIR.0b013e31826e1058 [pii] [published Online First: 2012/08/28]
33. Leonardi S, Armstrong PW, Schulte PJ, et al. Implementation of standardized assessment and reporting of myocardial infarction in contemporary randomized controlled trials: a systematic review. *Eur Heart J* 2013;34(12):894-902d. doi: 10.1093/eurheartj/eht003

eht003 [pii] [published Online First: 2013/01/29]
34. WMA Declaration of Helsinki - Ethical Principles for Medical Research Involving Human Subjects. Available from www.wma.net/en/30publications/10policies/b3/index.html (accessed 17 October 2012).

35. Caironi P, Tognoni G, Masson S, Fumagalli R, Persenti A, Romero M, et al. Albumin replacement in patients with severe sepsis or septic shock. N Engl J Med. 2014. doi: 10.1056/NEJMoa1305727.
36. Koenker R, Bassett G. Regression quantiles. *Econometrica* 1978;46:33–50.
37. Wu CFJ. Jackknife, bootstrap and other resampling methods in regression analysis. *Ann Stat* 1986;14:1261-350.
38. He X, Hu F. Markov chain marginal bootstrap. *J Am Stat Assoc* 2002;97:783-95.
39. Koenker R, Machado JAF. Goodness of fit and related inference processes for quantile regression. *Journal of the American Statistical Association* 1999;94:1296–310.
40. Gornall BF, Myles PS, Smith CL, et al. Measurement of quality of recovery using the QoR-40: a quantitative systematic review. *Br J Anaesth* 2013;111(2):161-9. doi: 10.1093/bja/aet014

aet014 [pii] [published Online First: 2013/03/09]
41. Liu VX, Rosas E, Hwang J, et al. Enhanced Recovery After Surgery Program Implementation in 2 Surgical Populations in an Integrated Health Care Delivery System. *JAMA Surg* 2017:e171032. doi: 10.1001/jamasurg.2017.1032 [published Online First: 2017/05/12]
42. Yadla S, Ghobrial GM, Campbell PG, et al. Identification of complications that have a significant effect on length of stay after spine surgery and predictive value of 90-day readmission rate. *J Neurosurg Spine* 2015;23(6):807-11. doi: 10.3171/2015.3.spine14318 [published Online First: 2015/09/01]
43. Berwick DM, Nolan TW, Whittington J. The triple aim: care, health, and cost. *Health Aff (Millwood)* 2008;27(3):759-69. doi: 10.1377/hlthaff.27.3.759
44. Lee VS, Kawamoto K, Hess R, et al. Implementation of a Value-Driven Outcomes Program to Identify High Variability in Clinical Costs and Outcomes and Association With Reduced Cost and Improved Quality. *Jama* 2016;316(10):1061-72. doi: 10.1001/jama.2016.12226 [published Online First: 2016/09/14]
45. Bauer M, Fitzgerald L, Haesler E, et al. Hospital discharge planning for frail older people and their family. Are we delivering best practice? A review of the evidence. *J Clin Nurs* 2009;18(18):2539-46. doi: 10.1111/j.1365-2702.2008.02685.x [published Online First: 2009/04/21]
46. Birkmeyer JD, Gust C, Dimick JB, et al. Hospital quality and the cost of inpatient surgery in the United States. *Ann Surg* 2012;255(1):1-5. doi: 10.1097/SLA.0b013e3182402c17
47. Jencks SF, Williams MV, Coleman EA. Rehospitalizations among patients in the Medicare fee-for-service program. *N Engl J Med* 2009;360(14):1418-28. doi: 10.1056/NEJMsa0803563
48. Zuckerman RB, Sheingold SH, Orav EJ, et al. Readmissions, Observation, and the Hospital Readmissions Reduction Program. *N Engl J Med* 2016;374(16):1543-51. doi: 10.1056/NEJMsa1513024
49. Danino JF, Taylor T, Metcalfe CW, et al. Readmission rates and financial penalties after ear, nose and throat surgery: how can we improve? *Br J Hosp Med (Lond)* 2015;76(11):655-7. doi: 10.12968/hmed.2015.76.11.655
50. Hannan EL, Zhong Y, Lahey SJ, et al. 30-Day Readmissions After Coronary Artery Bypass Graft Surgery in New York State. *JACC: Cardiovascular Interventions* 2011;4(5):569-76. doi: http://dx.doi.org/10.1016/j.jcin.2011.01.010
51. Ahmed J, Khan S, Lim M, et al. Enhanced recovery after surgery protocols - compliance and variations in practice during routine colorectal surgery. *Colorectal Dis* 2012;14(9):1045-51. doi: 10.1111/j.1463-1318.2011.02856.x [published Online First: 2011/10/12]
52. Group EC. The Impact of Enhanced Recovery Protocol Compliance on Elective Colorectal Cancer Resection: Results From an International Registry. *Ann Surg* 2015;261(6):1153-9. doi: 10.1097/SLA.0000000000001029
53. Myles PS, Devereaux PJ. Pros and cons of composite endpoints in anesthesia trials. *Anesthesiology* 2010;113(4):776-8. doi: 10.1097/ALN.0b013e3181ee2ceb [published Online First: 2010/09/03]

54. Ferreira-Gonzalez I, Permanyer-Miralda G, Busse JW, et al. Composite outcomes can distort the nature and magnitude of treatment benefits in clinical trials. *Ann Intern Med* 2009;150(8):566-7. doi: 150/8/566-b [pii] [published Online First: 2009/04/22]
55. Pogue J, Thabane L, Devereaux PJ, et al. Testing for heterogeneity among the components of a binary composite outcome in a clinical trial. *BMC Med Res Methodol* 2010;10:49. doi: 10.1186/1471-2288-10-49
56. Khuri SF, Henderson WG, DePalma RG, et al. Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. *Ann Surg* 2005;242(3):326-41; discussion 41-3. doi: 00000658-200509000-00004 [pii] [published Online First: 2005/09/02]
57. Myles PS, Peyton P, Silbert B, et al. Perioperative epidural analgesia for major abdominal surgery for cancer and recurrence-free survival: randomised trial. *BMJ* 2011;342:d1491. doi: 10.1136/bmj.d1491

bmj.d1491 [pii] [published Online First: 2011/03/31]
58. Sheingold SH, Zuckerman R, Shartzer A. Understanding Medicare Hospital Readmission Rates And Differing Penalties Between Safety-Net And Other Hospitals. *Health Aff (Millwood)* 2016;35(1):124-31. doi: 10.1377/hlthaff.2015.0534

Legend

Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

Table 1. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Types of Surgery.

Surgery	No. of patients	No. admitted to a rehabilitation hospital (%)	Median (95% CI) DAH_{30}†
Cardiac	679	54 (8.0)	22.8 (22.6-22.9)
Orthopaedic	289	122 (42)	21.9 (21.2-22.6)
Neurosurgery	220	9 (4.0)	22.8 (22.2-23.5)
Colorectal	118	8 (6.8)	24.9 (23.9-26.0)
Urology	315	26 (8.3)	23.8 (23.0-24.5)
Vascular	56	1 (1.8)	26.0 (24.3-27.3)
Ear, nose, throat	99	17 (17)	25.8 (24.9-27.0)
Oesophagogastric/hepatobiliary	253	4 (1.6)	24.9 (23.8-26.1)
Thoracic	28	2 (7.1)	22.8 (17.8-27.8)
Other	52	2 (3.8)	28.8 (27.7-30.0)

† hospital days do not include those spent in a rehabilitation facility

Table 2. Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.

Variable	no. (%)	Raw median DAH_{30} (95% CI)	P value	Adjusted median DAH_{30} (95% CI)†	P-value
Patient age			<0.001		<0.001
<50 years	220 (11)	24.9 (24.4 - 25.4)		24.8 (24.4 - 25.2)	
50-60 years	396 (19)	24.0 (23.4 - 24.6)		24.4 (24.0 - 24.9)	
60-70 years	612 (29)	23.9 (23.8 - 24.0)		24.0 (23.6 - 24.3)	
70-80 years	653 (31)	22.8 (22.6 - 23.0)		23.0 (22.7 - 23.4)	
≥80 years	228 (11)	22.7 (22.0 - 23.5)		22.2 (21.7 - 22.7)	
Sex			0.042		0.14
Male	1427 (68)	23.7 (23.1 - 24.2)		23.7 (23.5 - 24.0)	
Female	682 (32)	24.0 (23.7 - 24.2)		23.5 (23.2 - 23.8)	
Smoker			0.094		
yes	787 (37)	23.2 (22.6 - 23.8)		not done	
no	1322 (63)	23.8 (23.7 - 23.9)		not done	
Diabetes			0.003		
yes	697 (33)	23.0 (22.4 - 23.6)		not done	
no	1412 (67)	23.8 (23.8 - 23. 9)		not done	
Heart failure					
yes	365 (17)	22.9 (22.4 - 23.4)	0.002	not done	
no	1744 (83)	23.8 (23.7 - 23.9)		not done	
ASA physical status					<0.001
1	41 (1.9)	28.0 (26.3 - 29.7)	<0.001	25.9 (25.1 - 26.6)	
2	530 (25)	25.0 (24.7 - 25.3)		24.4 (24.0 - 24.7)	
3	1024 (51)	23.7 (23.1 - 24.3)		23.6 (23.2 - 23.9)	
4	510 (24)	22.0 (21.4 - 22.5)		23.0 (22.6 - 23.3)	
Duration of Surgery, h			<0.001		<0.001
<2.0	581 (29)	25.9 (25.7 - 26.1)		25.6 (25.2 - 26.0)	
2.0-2.99	412 (20)	24.0 (23.5 - 24.5)		24.0 (23.7 - 24.3)	
3.0-3.99	551 (26)	22.9 (22.8 - 23.1)		23.1 (22.7 - 23.4)	
≥4.0	565 (27)	21.9 (21.4 - 22.3)		22.0 (21.6 - 22.5)	

†covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table 3. Median (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value†
Myocardial infarction (120 [6.5])	1846	20.8 (19.2 - 22.4)	23.8 (23.7 - 23.9)	<0.001
Stroke (13 [0.7])	1846	10.1 (2.5 - 17.7)	23.8 (23.5 - 24.0)	<0.001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.4 - 25.9)	23.7 (23.5 - 24.0)	0.012
Cardiac arrest (3 [0.2])	1846	17.7 (0.9 - 34.5)	23.7 (23.5 - 24.0)	0.018
Surgical site infection (129 [7.0])	1846	21.0 (19.0 - 23.0)	23.8 (23.7 - 23.9)	<0.001
Any of the above (263 [14.2])	1846	20.5 (19.1 - 21.9)	23.9 (23.8 - 23.9)	<0.001
Hospital readmission (150 [7.1])	2090	17.9 (16.3 - 19.5)	23.9 (23.8 - 23.9)	<0.001

† P values calculated using the quasi- likelihood ratio test.

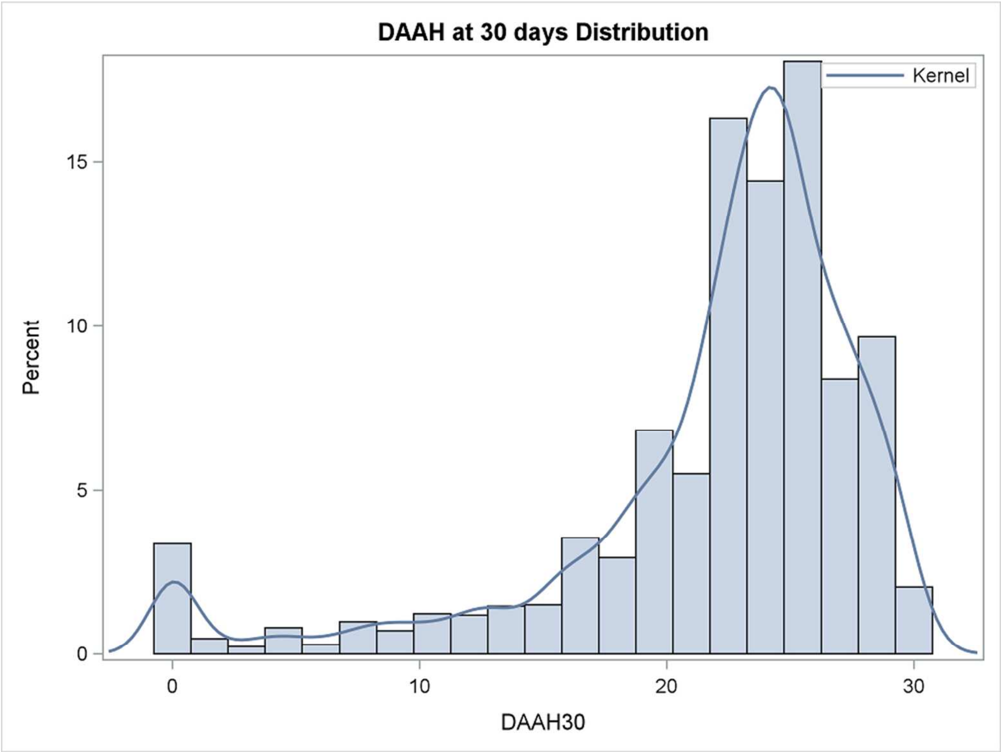


Figure 1. Frequency Distribution of Days at Home up to 30 Days after Surgery (n=2109). The smoothing line (kernel) is a non-parametric estimate of the probability density function.

84x63mm (300 x 300 DPI)

Supplementary Appendix

This appendix has been provided by the authors to give readers additional information about their work.

Supplement to: Days Alive and at Home after Surgery

Proposed Method of Calculation of "Days at Home within 30 days of Surgery" (DAH_{30})

DAH_{30} is a composite measure incorporating hospital length of stay in the hospital following the index surgery, re-admission to either the index or any other hospital, and including post-acute hospital discharge to a rehabilitation centre/hospital or other nursing facility, and early deaths after surgery, into a single outcome metric.

DAH_{30} is a numerical outcome measure that provides greater statistical power to detect clinically important differences in outcome. It is likely that a 0.5 day difference would be clinically important and valued by most people. A hospital bed day has been costed at £400 by the NHS in the UK, and $1800 in the US. It has the potential to increase the available hospital beds by about 8%.

By its very nature, DAH_{30} will be left-skewed with a spike at 0 (reflecting in-hospital deaths and those still admitted to hospital or other nursing facility at 30 days after surgery).

DAH_{30} is calculated using mortality and hospitalisation data from the date of the index surgery (= Day 0). For example, if a patient died on day 2 after their surgery whilst still an inpatient, they would be assigned 0 $DAH_{30;}$ if a patient was discharged from hospital on Day 6 after surgery but was subsequently readmitted for 4 days before their second hospital discharge, then they would be assigned 20 DAH_{30}. If a patient has complications and spends 16 days in hospital, and then is transferred to a nursing facility for rehabilitation, and spend 24 days there before finally being discharged to their own home, they would be assigned 0 DAH_{30}. (30-16-24 = -10, but the minimum value of DAH_{30} should be zero*).

Patients having a planned re-admission (eg. removal of a stent or secondary closure of a fistula) within 30 days of surgery should have these days subtracted from the total DAH_{30}. That is, if a patient is discharged from hospital on Day 13, and is electively re-admitted two weeks later (Day 27) for a further 2 days, their DAH_{30} will be calculated as 30-13-2 (=15).

Important: If a patient dies within 30 days of surgery, irrespective of whether they have spent some time at home, DAH_{30} should be scored as zero (0).

*an alternative would be to use DAH_{90} (up to 90 days after surgery) as an outcome metric in circumstances where a longer postoperative recovery is expected.

Table S1. Trial Data Sources

Trial	N	Reference
1. Tranexamic acid in coronary artery surgery	613	N Engl J Med 2016; Oct
2. The safety of addition of nitrous oxide to general anaesthesia in at-risk patients having major non-cardiac surgery (ENIGMA-II): a randomised, single-blind trial	516	Lancet 2014; 384:1446-54.
3. An enhanced recovery after surgery (ERAS) program for hip and knee arthroplasty	310	Med J Aust 2015; 202:363-8.
4. Experience of an enhanced recovery after surgery (ERAS) program for elective abdominal surgery	71	Anaesth Intensive Care 2012; 40:450-9.
5. The measurement of disability-free survival after surgery	163	Anesthesiology 2015; 122:524-36.
6. Perioperative management of patients treated with angiotensin converting enzyme inhibitors and angiotensin II receptor blockers: a quality improvement audit	263	Anaesth Intensive Care 2016; 44:346-52.
7. Restrictive versus liberal fluid therapy in major abdominal surgery	173	ClinicalTrials.gov NCT01424150

Figure S1. The impact of the quantile (50th – 75th percentile) choice for days at home up to 30 days (here, DAAH30) on the associations of patient age category, ASA physical status and surgical duration, demonstrating the covariates are reasonably stable over this range.

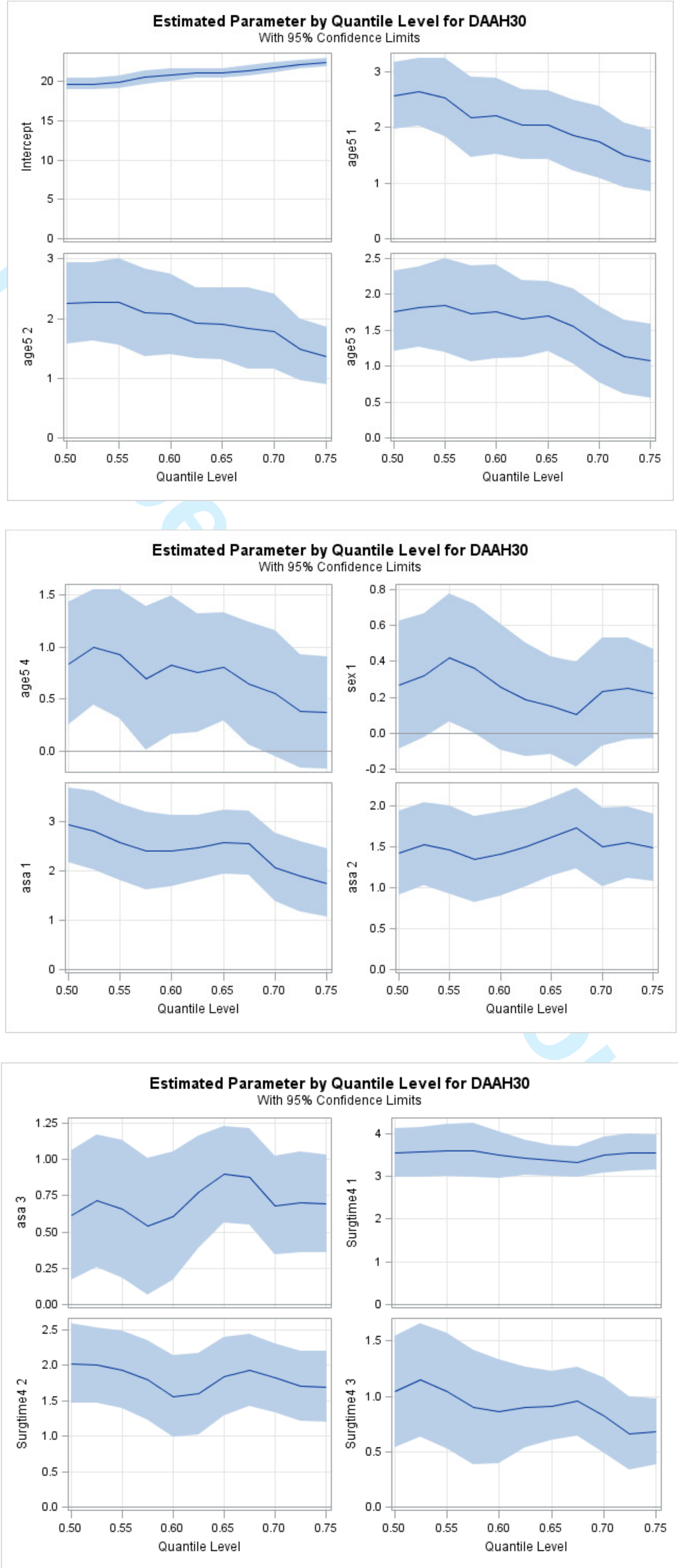


Table S2. Third Quartile (Q3) Days at Home up to 30 Days after Surgery (DAH_{30}) According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw Q3 DAH_{30} (95% CI)	P value	Adjusted Q3 DAH_{30} (95% CI)*	P-value
Patient age					
<50 years	220 (11)	27.2 (26.5 , 27.9)	<.0001	26.1 (25.8 , 26.5)	<0.0001
50-60 years	396 (19)	25.9 (25.5 , 26.4)		26.1 (25.9 , 26.4)	
60-70 years	612 (29)	25.7 (25.0 , 26.4)		25.8 (25.6 , 26.1)	
70-80 years	653 (31)	25.0 (24.6 , 25.4)		25.1 (24.8 , 25.4)	
≥80 years	228 (11)	24.8 (24.3 , 25.3)		24.7 (24.1 , 25.4)	
Sex					
Male	1427 (68)	25.1 (24.8 , 25.4)	<.0001	25.6 (25.5 , 25.8)	0.146
Female	682 (32)	26.2 (25.6 , 26.8)		25.4 (25.2 , 25.7)	
Smoker					
yes	787 (37)	25.0 (24.8 , 25.1)	<.0001	not done	
no	1322 (63)	26.0 (25.7 , 26.2)		not done	
Diabetes					
yes	697 (33)	25.8 (25.1 , 26.5)	>.99	not done	
no	1412 (67)	25.8 (25.6 , 26.0)		not done	
Heart failure					
yes	365 (17)	25.9 (25.2 , 26.7)	0.39	not done	
no	1744 (83)	25.8 (25.4 , 26.2)		not done	
ASA physical status					
1	41 (1.9)	29.0 (28.8 , 29.3)	<.0001	26.6 (26.0 , 27.2)	<0.0001
2	530 (25)	27.0 (26.9 , 27.1)		26.3 (26.0 , 26.6)	
3	1024 (51)	25.8 (25.3 , 26.3)		25.5 (25.3 , 25.8)	
4	510 (24)	23.9 (23.8 , 24.0)		24.8 (24.5 , 25.1)	
Duration of Surgery, h					
<2.0	581 (29)	28.1 (27.7 , 28.6)	<.0001	27.6 (27.3 , 28.0)	<0.0001
2.0-2.99	412 (20)	26.1 (25.6 , 26.5)		25.8 (25.4 , 26.2)	
3.0-3.99	551 (26)	24.8 (24.7 , 24.9)		24.8 (24.5 , 25.0)	
≥4.0	565 (27)	23.9 (23.8 , 23.9)		24.1 (23.8 , 24.4)	

The effect of the different covariates were largely consistent across a large range of meaningful percentile values (e.g. 50^{th} – 75^{th}) with a slightly smaller effect for age categories as the percentile gets higher but for simplicity we only present the results for Q3 (75^{th} percentile). This percentile is also close to the main mode of the distribution.

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

Table S3. Third Quartile (Q3) (95% CI) Days at Home up to 30 Days after Surgery According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	22.9 (22.2 - 23.5)	25.8 (25.4 - 26.2)	<0.0001
Stroke (13 [0.7])	1846	18.9 (10.0 - 27.8)	25.2 (24.6 - 25.7)	0.019
Pulmonary embolism (7 [0.4])	1846	23.1 (16.1 - 30.1)	25.2 (24.6 - 25.7)	0.19
Cardiac arrest (3 [0.2])	1846	20.1 (8.0 - 32.1)	25.2 (24.6 - 25.7)	0.052
Surgical site infection (129 [7.0])	1846	24.8 (23.7 - 26.0)	25.3 (24.7 - 25.9)	<0.0001
Any of the above (263 [14.2])	1846	23.7 (23.0 - 24.5)	25.8 (25.6 - 26.1)	<0.0001
Hospital readmission (150 [7.1])	2090	21.7 (20.8 - 22.7)	25.9 (25.8 - 26.0)	<0.0001

[a] P values calculated using likelihood ratio test.

Table S4. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.

Surgery	No. admitted to a rehabilitation hospital (%)	Mean (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.7-22.9)
Orthopaedic (n=289)	122 (42)	21.9 (21.2-22.6)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (24.1-25.8)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.9-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

Table S5. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.∞

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value#
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.5 - 25.2)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.5 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.2 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.4 (20.4 - 22.4)	
Sex			0.90		0.0052
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.4 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			>0.99		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.6 - 23.4)			
Diabetes			0.091		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.6 - 23.8)			
Heart failure			0.16		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status					
1	41 (1.9)	27.9 (26.1 - 29.7)		25.3 (24.3 - 26.3)	<0.0001
2	530 (25)	24.9 (24.6 - 25.1)	<0.0001	24.0 (23.6 - 24.5)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.3)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.3)		23.6 (23.2 - 24.0)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery

#P values calculated using the quasi-likelihood ratio test.

∞ If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S6. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 5 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.*

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.6 - 21.5)	23.1 (22.6 - 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.7 - 16.5)	23.0 (22.8 - 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.0 - 26.3)	23.0 (22.7 - 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.7 - 29.4)	23.0 (22.8 - 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (18.9 - 22.6)	23.1 (22.6 - 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 - 20.8)	23.7 (23.3 - 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 - 19.0)	23.7 (23.3 - 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.
[b] days calculated for those without readmission after excluding postoperative deaths.

* If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S7. Days at Home up to 30 Days after Surgery ($DAH_{30\text{-rehab}}$), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Types of Surgery.*

Surgery	No. admitted to a rehabilitation hospital (%)	Median (95% CI) $DAH_{30\text{-rehab}}$
Cardiac (n=679)	54 (8.0)	22.8 (22.6-22.9)
Orthopedic (n=289)	122 (42)	20.9 (17.5-24.4)
Neurosurgery (n=220)	9 (4.0)	22.8 (22.2-23.5)
Colorectal (n=118)	8 (6.8)	24.9 (23.9-26.0)
Urology (n=315)	26 (8.3)	23.8 (23.0-24.5)
Vascular (n=56)	1 (1.8)	26.0 (24.4-27.6)
Ear, nose, throat (n=99)	17 (17)	25.8 (24.3-27.3)
Oesophagogastric/hepatobiliary (n=253)	4 (1.6)	24.9 (23.8-26.1)
Thoracic (n=28)	2 (7.1)	22.8 (17.8-27.8)
Other (n=52)	2 (3.8)	28.8 (27.7-30.0)

*If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S8. Days at Home up to 30 Days after Surgery (DAH_{30}), Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Patient and Perioperative Characteristics.#

Variable	no. (%)	Raw median $DAH_{30\text{-rahab}}$ (95% CI)	P value	Adjusted median $DAH_{30\text{-rahab}}$ (95% CI)*	P value
Patient age			<0.0001		<0.0001
<50 years	220 (11)	24.9 (24.4 - 25.3)		24.6 (24.2 - 25.1)	
50-60 years	396 (19)	23.9 (23.6 - 24.3)		24.5 (24.0 - 25.0)	
60-70 years	612 (29)	23.8 (23.5 - 24.1)		23.6 (23.3 - 24.0)	
70-80 years	653 (31)	22.0 (21.5 - 22.4)		22.5 (21.9 - 23.1)	
≥80 years	228 (11)	20.9 (19.6 - 22.2)		21.5 (20.5 , 22.4)	
Sex			0.84		0.0065
male	1427 (68)	23.0 (22.6 - 23.4)		23.6 (23.3 - 23.9)	
female	682 (32)	23.0 (22.3 - 23.6)		22.7 (22.2 - 23.3)	
Smoker			0.92		
yes	787 (37)	23.0 (22.5 - 23.5)			
no	1322 (63)	23.0 (22.5 - 23.4)			
Diabetes			0.12		
yes	697 (33)	22.8 (22.6 - 23.1)			
no	1412 (67)	23.2 (22.5 - 23.8)			
Heart failure			0.19		
yes	365 (17)	22.8 (22.3 - 23.3)			
no	1744 (83)	23.1 (22.6 - 23.7)			
ASA physical status			<0.0001		<0.0001
1	41 (1.9)	27.9 (26.0 - 29.8)		25.3 (24.2 - 26.3)	
2	530 (25)	24.9 (24.6 - 25.1)		24.1 (23.6 - 24.6)	
3	1024 (51)	22.9 (22.7 - 23.1)		23.1 (22.7 - 23.5)	
4	510 (24)	21.9 (21.5 - 22.4)		22.9 (22.4 - 23.4)	
Duration of Surgery, h			<0.0001		<0.0001
<2.0	581 (29)	25.8 (25.1 - 26.4)		25.4 (24.9 - 26.0)	
2.0-2.99	412 (20)	23.8 (23.3 - 24.4)		23.6 (23.2 - 24.1)	
3.0-3.99	551 (26)	22.8 (22.7 - 23.0)		22.7 (22.3 - 23.1)	
≥4.0	565 (27)	21.8 (21.0 - 22.5)		21.6 (20.9 - 22.2)	

*covariates including in the multivariable adjustment were: patient age, sex, American Society of Anesthesiologists (ASA) physical status and duration of surgery.
#If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

Table S9. Median (95% CI) Days at Home up to 30 Days after Surgery, Assuming 14 Days' Admission to a Rehabilitation Facility if it Occurred, According to Postoperative Complications.

Variable (no. [%])	No. with complete data	Yes	No	P value[a]
Myocardial infarction (120 [6.5])	1846	19.0 (16.5 , 21.6)	23.1 (22.6 , 23.7)	<0.0001
Stroke (13 [0.7])	1846	10.1 (3.4 , 16.9)	23.0 (22.8 , 23.2)	<0.0001
Pulmonary embolism (7 [0.4])	1846	17.1 (8.3 , 26.0)	23.0 (22.7 , 23.2)	0.032
Cardiac arrest (3 [0.2])	1846	15.1 (0.4 , 29.8)	23.0 (22.8 , 23.2)	0.0065
Surgical site infection (129 [7.0])	1846	20.7 (19.0 , 22.5)	23.1 (22.6 , 23.6)	<0.0001
Any of the above (263 [14.2])	1846	19.1 (17.5 , 20.8)	23.7 (23.3 , 24.1)	<0.0001
Hospital readmission (150 [7.1])	2090	17.2 (15.4 , 18.9)	23.7 (23.3 , 24.1)[b]	<0.0001

[a] P values calculated using the quasi-likelihood ratio test.

[b] Days calculated for those without readmission after excluding postoperative deaths. If a patient has spent less than 5 days at home and went to rehab, $DAH_{30\text{-rehab}}$ is set to 0 to avoid negative values.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4,5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7,8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	8
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, explain how loss to follow-up was addressed	n/a
		(*e*) Describe any sensitivity analyses	10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	9
		(c) Consider use of a flow diagram	Not used
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, Table 2
		(b) Indicate number of participants with missing data for each variable of interest	n/a
		(c) Summarise follow-up time (eg, average and total amount)	9
Outcome data	15*	Report numbers of outcome events or summary measures over time	10,22
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12,15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	1

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.