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Home health monitoring around the time of surgery: a qualitative study of patients' experiences before and after joint replacement

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Complete List of Authors:	Grant, Sabrina; University of Bristol School of Clinical Science, Musculoskeletal Research Unit Blom, AW; University of Bristol, Musculoskeletal Research Unit; National Institute for Health Research, Bristol Biomedical Research Centre, University Hospitals Bristol NHS Foundation Trust and University of Bristol, UK Craddock, Ian ; University of Bristol, SPHERE-IRC, Merchant Venturers Building, Level 0, Dept of Electrical and Electronic Engineering, Faculty of Engineering, University of Bristol, Woodland Road, BS8 1UB Whitehouse, Micheal ; University of Bristol, Musculoskeletal Research Unit, Translational Health Sciences, Bristol Medical School, Learning and Research Building, Level 1, Southmead Hospital, Southmead, BS10 5NB; National Institute for Health Research Bristol Biomedical Research Centre, University of Bristol Goberman-Hill, Rachael; University of Bristol, Bristol Medical School; National Institute for Health Research, Bristol Biomedical Research Centre, University Hospitals Bristol NHS Foundation Trust and University of Bristol, UK
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5 **Home health monitoring around the time of surgery: a qualitative study of patients' experiences**
6 **before and after joint replacement**
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8
9 Authors: Grant S¹, Blom AW^{1,3}, Craddock I², Whitehouse MR^{1,3}, Gooberman-Hill R^{1,3}
10

11 ¹ Musculoskeletal Research Unit, Translational Health Sciences, Bristol Medical School, University of
12 Bristol, Learning and Research Building, Level 1, Southmead Hospital, Southmead, Bristol, BS10 5NB,
13 UK

14 ² SPHERE-IRC, Digital Health, 1 Cathedral Square, Trinity Street, Bristol, BS1 5DD, UK

15 ³ National Institute for Health Research Bristol Biomedical Research Centre, University Hospitals
16 Bristol NHS Foundation Trust and University of Bristol, UK
17

18
19 Corresponding author: Dr Sabrina Grant, sabrina.grant@bristol.ac.uk, +44 117 414 7852
20

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Abstract

Objectives: Hip and knee replacements are common major elective surgical interventions with over 200,000 performed annually in the UK. The number of patients needing these operations are set to increase therefore innovative evaluation of surgical outcomes are needed. This aim of this qualitative study was to capture patient experience of living with a novel home monitoring sensing system during the period around joint replacement.

Setting: One secondary care hospital in the South West, UK

Participants: 13 patients, (8 female, 63-89y) undergoing total hip or knee replacement enrolled onto the study

Design: Qualitative study with thematic analysis. The system remained in situ for up to 12 weeks after their surgery and comprised a group of low powered sensors monitoring the environment and activity of people within the home. Patients were interviewed at two timepoints: before and after surgery. Interviews explored views about living with the technology, its acceptability as well as attitudes towards health technology.

Results: Three main themes emerged: installation of home sensing technology on the journey to surgery; the home space and defining unobtrusiveness and pivotal role of social support networks

Conclusions: A home sensing system that monitors the environment and activity of the people in the home could provide an acceptable and innovative way of assessing patients' surgical outcomes. At a time characterised by reduced mobility, functional limitations and increased pain it should however be considered that patients depended on informal and formal supportive networks to help maintain the system through the busy trajectory of surgery.

Strengths and limitations of this study

- Patients were able to experience the home technology under real circumstances by living with it before and after surgery
- In-depth one-to-one interviews provided insight into patients' real experiences and views as they lived with the technology in their own homes
- Although the sample size was small and lacked ethnic diversity, there was diversity in age, gender and patients undergoing hip and knee replacement
- Use of thematic analysis enabled robust analysis of data, including focus on the acceptability of the technology in real health-related circumstances.

INTRODUCTION

1
2
3 For people living with osteoarthritis or other forms of joint disease that has not responded to non-
4 operative treatments, total hip or knee replacement may be provided. Numbers of these procedures
5 are rising and continue to do so as the population ages: in 2017 alone, 91,698 primary total hip and
6 102,177 knee replacements were performed in England, Wales, Northern Ireland and the Isle of
7 Man.[1, 2] Having a total hip or knee replaced involves removal of the affected joint and its
8 replacement with prosthesis implants.
9

10
11 Longitudinal cohort studies have shown that up to 20% of patients are not entirely satisfied with the
12 outcome of their joint replacement.[3] Brander et al. reported one in eight patients still had
13 substantial pain one year after surgery despite 'well-fitting' and functioning implants.[4] Wylde et al.
14 found that two years following surgery, 11% of patients thought function was the same or worse
15 than it was pre-operatively.[5]
16

17
18 Post-operative care remains the responsibility of the hospital providing the intervention and follow
19 up will be arranged with the surgical team, support may also be provided by a different health care
20 team. This may involve the patient consulting their GP or other primary care healthcare
21 professionals (PHCPs) if they encounter complications following the operation. Patients may also
22 require the support of those closest to them. This entire process may have been anticipated in the
23 preparatory phase but often, unanticipated consequences or events occur, and everyone will have
24 different ways of coping and adjusting to such consequences and life after surgery. Helping people
25 to recover well after such major surgery is paramount, and a key aspect of this is assessing recovery
26 on return home from hospital. We need better understanding of the reasons why many patients are
27 not entirely satisfied with their outcomes. The provision of efficient and responsive mechanisms for
28 monitoring that may indicate when things are going well or when medical attention might be
29 required outside of the normal planned follow up regimes, which tend not to be individualised, may
30 lead to improved patient care.
31
32

33
34 Information technology is already woven into many aspects of patients' lives. In a health context,
35 technology may provide the possibility for older adults with chronic conditions and complex needs
36 to remain at home and maintain an acceptable quality of life.[6] Technologies for use at home may
37 include 'wearable sensors to detect changes in vital signs,[7] functional monitoring, emergency fall
38 detection[8, 9]and cognitive and sensory assistance.[10]
39

40
41 A review of research up to 2017 focusing on the use of technology in the home, remote monitoring
42 systems and design of better environments for older people[11] indicated that despite an increase in
43 studies focusing on local services and equipment that are patient-centred in design, many clinicians
44 may be reluctant to accept change due to a lack of education in this emerging field and how it
45 affects their patients. Also highlighted was the importance of research to understand the needs and
46 experiences of older people and how these technologies are used. Evidence from studies that show
47 how this technology can be used by people in a variety of contexts and with various health
48 conditions or needs can help to develop improvements to technology.[12]
49

50
51 To ensure technologies are developed in ways that make them fit for purpose and acceptable, there
52 is a need to understand and characterise the views of the people who have experience of using
53 them. The Hip and KnEe Study of a Sensor Platform of Healthcare in a Residential Environment
54 (HEmiSPHERE) aimed to assess the acceptability of home monitoring system for patients in the NHS
55 who were undergoing hip or knee replacement.[13] We describe qualitative research within
56 HEmiSPHERE that explored and characterised patients' experiences of this technology.
57
58
59
60

METHODS

The HEmiSPHERE study embedded within a broader project: 'A Sensor Platform of Healthcare in a Residential Environment' (SPHERE) is an interdisciplinary research project that has developed sensor technology to monitor home environments.[14] The SPHERE system comprises a group of low power sensors that can continuously measure anonymised, time-stamped information about the home (e.g. temperature, humidity), this includes appliance monitors to capture use of electricity, and sensors to collect information about movement through silhouettes (body outlines). The system also a wearable wristband that collects accelerometry information about movement within their home. Collectively the system can measure location, activity, quality and extent of movement. The system requires minimal input from individuals in their homes, and as such it is a 'passive' monitoring system.[11] To date, the SPHERE sensor system has been installed in a total of 52 homes in the South West of England, of which 13 were homes of people undergoing hip or knee replacement and who comprise the sample for this study.[14]

Sample

13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled and enrolled onto the study. Participants were aged between 63 and 89 years and comprised 5 men and 8 women, with 10 undergoing hip replacement and 3 undergoing knee replacement. Demographic information about the 13 participants is displayed in Table 1. All names are pseudonyms.

Insert Table 1 – Participant Demographics

Recruitment

All participants provided written consent before taking part during the initial planning home visit. Patients placed on the waiting list for a total hip or knee replacement were identified and recruited from one orthopaedic centre in the South West of England. Recruitment took place initially by postal methods, mailed an information pack (invitation letter, information booklet detailing purposes of the study, description including images of the sensor system, installation procedures and detailed information about how their data would be used and stored and reply slip). Participants returning the reply slip were contacted by the study researcher (SG) and invited to the study. Patients were also screened for eligibility at their pre-operative consultation by their treating consultant and then approached in clinic by a researcher to explain the study, provide an information booklet and invited to study.

Eligibility Criteria

Adults who could read and understand English. As the study focused on the views of people undergoing hip or knee replacement for osteoarthritis, we designed the study consent procedures for an adult population. Participants were excluded if children (16 and under) resided within the patients' home.

Data collection and analysis

All data collection took place within the home. The SPHERE system was installed approximately two weeks before the patient's surgery date (Figure 1) and continued to monitor the household before, during and up to twelve weeks after surgery.

[Insert Figure 1 – Flow chart of patient through the HEmiSPHERE study]

Interviews were conducted by an experienced qualitative researcher (SG) with all patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint 2, T2) surgery. Background

of the interviewer was not disclosed to participants. In-depth interviews using probes and prompts provides understanding of lived experiences.[15] Each interview took place in the participant's home. On occasion, a household member was present. Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[16] Supplementary field notes were taken after the interview. All participants' names were replaced with pseudonyms, and identifiable information was removed. Interviews lasted between 45 and 60 minutes and open-ended questions followed topic guides (Box 1). Participants and interviewer were not known to each other prior to study commencement.

Box 1 Topic Guides

Pre-surgery (Timepoint 1; T1)

- Route to referral for surgery
- People living in the household
- Previous experience of health technology (home, wearable, apps)
- Current experience and future expectations of mobility and function
- Preparations in the household for surgery

Post-surgery (Timepoint 2; T2)

- Experience of aftercare post-surgery
- Experience of living with SPHERE technology
- Ask about the adequacy of information received about SPHERE technology
- Explore how initial expectations of living with the SPHERE technology compared to the experience

Each interview at T1 began with an introduction to the aims of the interview, and a discussion of their route to referral, views about the SPHERE sensor system, household constitution and health technology usage. Interviews after surgery explored care after surgery and living with the SPHERE sensor system. Using thematic analysis [17] the researcher (SG) read and re-read the data to ensure familiarity, coding inductively before sorting coded data into themes. [15] Codes were checked for consistency and validation by a second experienced researcher in the department, and the study team (SG, RGH, MW, AB).

We consulted our PEP-R group regarding the development and analyses of transcripts and established criteria to inform our reporting of the qualitative study.[18]

Patient and Public Involvement

This study was developed in collaboration with the Patient Experience Partnership in Research, (PEP-R).[19] PEP-R is a patient involvement group, most of whom have had joint replacements, all of whom have had experiences of long term pain, some after knee replacement. PEP-R provide input into research prioritisation and provided specific input into the study design, including the materials such as recruitment documentation and interview topic guide. They also viewed and commented on feedback to participants. SPHERE's professional advisory group were consulted on the project as a whole and the design of study materials.

RESULTS

Of the 35 patients seen in clinic, 12 declined to participate (concerns of living alone and managing study requirements, too burdensome, family not keen) 5 withdrew after booking Visit A (i.e. verbal

1
2
3 agreement only). Of the 13 finally enrolled onto the study, 3 were recruited by post and one by
4 radio advertisement. Further details of recruitment are reported in Figure 2.
5

6 [Insert Figure 2 Participant recruitment]
7

8
9 We identified three main themes relating to acceptability of home monitoring technology:
10 installation of home sensing technology on the journey to surgery, the home space and defining
11 unobtrusiveness and pivotal role of social support networks. We include illustrative quotations from
12 participants, all names are pseudonyms and we indicate total hip replacement (THR) or total knee
13 replacement (TKR) and timepoint (T1 or T2) next to each quotation.
14

15 **Theme 1 – Installation of ‘home sensing technology’ on the journey to surgery**

16 On route to having hip or knee replacement, a patient can expect to receive numerous letters to
17 attend appointments with HCPs before the day of their operation. Patients may also make plans
18 with carers, friends or relatives about how best to recover and receive support in the weeks after
19 surgery. This presents a critical time when anticipation of surgery may result in a period of
20 heightened anxiety. We wanted to capture patients’ experiences of being recruited and having this
21 SPHERE sensor installed during this peak activity period.
22

23
24 All our patients were accepting of our approaches and contents of the information booklet.
25

26 *“Oh, it [study information booklet] was fine. I read it through, took it in, it seemed to*
27 *answer anything I wanted to know” (Mrs Wilson, 89y, TKR, T1)*
28

29 *“It [study visit] was okay, no it was plenty enough. Everybody’s been very careful to*
30 *explain every step of the way” (Mr Hayes, 70y, THR, T1)*
31

32
33 Providing a separate study information booklet tailored to household members gave additional
34 assurance for others living within the household from a different perspective to the patient.
35

36 *“No, I think it was fine and actually after you came the last time I said to [family*
37 *members’ names] ‘How was that? Do you want to ask me any questions and they said,*
38 *‘No, no, no. That was fine.’ It was fine and then I saw them looking through the leaflet*
39 *again the other night, so I think they’re quite happy as well” (Mrs Griffiths, 63y, THR, T1)*
40

41 In dealing with the complex detail of the study, many felt the study information booklet and SPHERE
42 user guide were useful to refer to.
43

44 *“Sometimes when you’re talking about different things to do with this thing [the SPHERE*
45 *system], you’re listening but you’re not really taking it in. You then think, ‘What did she*
46 *say about so and so?’ and then you flip through whatever” (Mr Russell, 67y, THR, T2)*
47

48
49 Patients and household members were shown the actual sensors (as opposed to images) and asked
50 to try on the wristband at the first visit. This helped them to understand the system in context of
51 their own home.
52

53 *“Well see I’m not very good at that sort of thing [technology] so what you’ve shown me*
54 *is enough, I mean I basically know what’s going on” (Mrs Evans, 85y, THR, T2)*
55

56
57 Patients were asked to remember some information about how to use the system. Some people
58 found this hard to recall or to act upon. For instance, remembering to charge the tablet could be
59 hard.
60

1
2
3 *"I have only charged it the once I think that I can remember ... I haven't bothered*
4 *switching it on and off" (Mr Connell, 67y, TKR, T1)*
5

6 Participants described altruistic reasons for taking part in the study, that is they were willing to take
7 part in the research to provide benefit to others in the future.
8

9
10 *"I thought well it [participation in the study] would be a bit intrusive, but you know I*
11 *think that everybody should do their bit to help the medical science to keep moving*
12 *forward so I just thought I you know I ought to agree" (Mr Hayes, 70y, THR, T1)*
13

14 *"Well I hope it will help somebody because you know it's, it probably won't help me*
15 *will it, I can't see how it can help me, but I can see it helping others" (Mrs Evans, 85y,*
16 *THR, T1)*
17

18 Participants did not make much use of existing health technologies such as blood pressure monitors.
19 Participants nonetheless could think of reasons how this technology could help other patients having
20 surgery.
21

22
23 *"I thought it [participation in the study] was a good idea. I did. If it's going to help*
24 *patients to recovery, it should be good. I'd hope it would help people who are having*
25 *operations like this" (Mr Price, 85y, THR, T1)*
26

27 Despite their preparation for major surgery, participants did not mind the level of contact required
28 for this study before and after the operation. In the event of technical problems, participants felt
29 they were dealt with satisfactorily but sometimes would have preferred a more rapid response.
30

31 *"I emailed but it was a Sunday afternoon and they [friends] were coming in the evening*
32 *but I couldn't get into the thing [Genie] as I had forgot the passcode and obviously I*
33 *didn't hear back until the following day when actually I rang again because nobody*
34 *responded to the email on the Monday but I rang and spoke to the young lady in your*
35 *office eventually. There was a little communication gap I think was all it was really*
36 *anyway, but that was fine. It was all, once I got the code I was fine" (Mr Hayes, 70y,*
37 *TKR, T1)*
38
39

40 Participants were accepting of having to understand and comply with detailed information and study
41 procedures despite a busy period in preparation for surgery. Thinking about the benefits for patients
42 in the future as a result of their participation in the study appeared to be a primary motivator to
43 allow this technology to be fitted and monitor their activity within the home.
44

45 **Theme 2 – The home space and defining unobtrusiveness**

46 Use of the home space before and after surgery was dynamic. Before the SPHERE system was
47 installed, participants provided detailed floorplans. These mapped areas of high traffic, where they
48 spent most or least time, and areas that they wished to retain privacy in and therefore have no
49 silhouette sensors installed (e.g. bathrooms or bedrooms). Some participants changed their use of
50 their home space during their post-surgical recovery, for instance by moving to a different room for
51 private activities or changing their preferred usual chair after surgery. In addition, movement around
52 the home depended on seasonal changes and visitors. Notably, participants said that visitors after
53 surgery came to help and used the home space in different ways compared with the time before
54 surgery.
55
56

57
58 *"When he's [husband] I'm here [in lounge] and also, it's warmer in there. So when,*
59 *you know, on a cold day it's warmer in there so we found ourselves sitting in there*
60

1
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3 *more ... when you asked me I thought, 'I'd probably stay here most of the time'. It's*
4 *only afterwards you think, 'Oh, I do go in there a lot'* (Mrs Thompson, 75y, THR, T2)
5

6 One patient spent most of their immediate post-operative recovery period in the lounge, washing
7 and dressing in that room rather than their bathroom and bedroom. By mutual agreement, the
8 SPHERE team removed the whole system from the house for this participant to protect their privacy
9 and dignity.
10

11
12 *"I'm still getting washed and dressed at the table there because we've only got a*
13 *tiny bathroom and it was not easy, it's not easy in there"* (Mrs Henry, 67y, THR,
14 T2)
15

16 Anticipating installation of the SPHERE system in the house, some participants expressed concerns
17 about internal damage to wall surfaces within the rooms. Some noted that the cabling for some of
18 the sensors did not match their expectations, which they had expected to be 'wireless'.
19

20
21 *"Well I did say to you before that I am amazed that they're not Wi-Fi or wireless.*
22 *Why do they have to be cabled, I do not understand but there you are. I'm sure*
23 *your technicians would know a lot more than me, it's pretty unsightly having*
24 *cabling running up walls, which it is in the lounge, in the back room and in here.*
25 *You know, makes what is fairly obvious even more".* (Mr Hayes, 70y, TKR, T1)
26

27 Despite concerns about aesthetics, most felt they did not have to pay much attention to the system
28 on a day-to-day basis. Participants were given the choice to switch the system off when they went
29 into hospital. All decided to keep the system running during this time. Some participants wondered if
30 they should be interacting more with the Genie, a tablet provided to the participant, which through
31 an installed app could control the whole system, pause or delete data within certain time frames.
32

33
34 *"Sorry, just while I think about it, so all I'm doing is just looking to see when this*
35 *needs charging? I'm not supposed to use the iPad for anything else? It would be*
36 *nice if people could use it while they're stuck at home? It might be an*
37 *encouragement for people to do the study ... I don't know. I don't know what the*
38 *take-up is of the study, whether it would be an extra thing that people could use it*
39 *for something, I don't know. But an app could be installed on it just to do*
40 *something."* [Mrs Thompson, 75y, THR, T2]
41

42
43 *"It was a bit, I sort of wasn't quite sure what I was supposed to be doing but I'd used it*
44 *just to check my batteries mainly."* [Mrs Harrison, 65y, THR, T2]
45

46 In the immediate post-operative recovery period, some patients experienced discomfort and post-
47 operative pain particularly in the area near the surgical wound. Adapting to the recovery phase
48 within the household, for instance working out how to position furniture to enable them to move
49 was challenging for many, particularly for patients living alone. With very little interaction with the
50 system day-to-day and concentration on recovery, some participants described how they
51 occasionally forgot to wear the wristband such as after showering or when leaving the house. Some
52 participants also described how they had not checked battery levels or had forgotten to put the
53 wristband back on after showering. They suggested further improvements to the system such as
54 adding warning lights on the wristband or for warnings to be indicated clearly on the study
55 information.
56

57
58 *"Maybe it should be in the brochure or somewhere in big letters "wear this all the*
59 *time, including when you are going to bed". You just think that it's useful for*
60

1
2
3 *recording when I walk from room to room and as going up the stairs. Because there is*
4 *no recording device in the bedroom, you don't think but you obviously connect the*
5 *wristband with one of those. Downstairs is where I should be wearing it. I certainly*
6 *take it off before I even climbs the stairs, unless I'm going to the toilet". (Mr Russell,*
7 *67y, THR, T2)*
8

9
10 *"Even if it could be on a sticker on the front. 'Wear this everywhere, apart from when*
11 *you're in the shower' that would be good and then I would wear it, especially now, and*
12 *wear it to bed. It's what people see and that's what they do. It doesn't matter about the*
13 *other thing about charging it up because they'll eventually think, 'It ought to be charged*
14 *by now'" (Mr Connell, 67y, TKR, T2)*
15

16 *"Yeah yeah and it's almost that said oh you are on that but flashed up, I don't know, like*
17 *a green light or something or your battery's going or something's going on it that*
18 *shouldn't it might be a good idea yeah" (Mrs Evans, 85y, THR, T2)*
19

20 Of the range of sensors within the SPHERE system, patients' experiences of the wearable wristband
21 varied. Most patients felt the wristband was acceptable.
22

23
24 *"Do you know what, I thought I'd find it annoying. I really did think I'd find it annoying*
25 *and that I would have to, because I don't even like to wear a watch, I do have a medical*
26 *alert and I keep that on but I don't even like wearing a wristwatch particularly. I like to*
27 *have my wrists free. Maybe because I'm not doing a lot of housework and washing, I'm*
28 *not getting in the garden digging, maybe I'm not so aware of it because I'm not*
29 *washing my hands a lot. So I sort of forgot about it, which surprised me a bit. So that's*
30 *quite nice". (Mrs Griffiths, 63y, THR, T2)*
31
32

33 However, some participants found the wristband inconvenient and sometimes took it off because of
34 this.
35

36 *"Yeah, it's the left hand as well and I'm not very good with my hands. It would be*
37 *better if it was a clip on or something like that. You could put it in there somewhere*
38 *rather than strapping it on your wrist because it is uncomfortable as well. It's not*
39 *uncomfortable as being annoying, sore or anything like that. It's just an inconvenience*
40 *... I've put it in my pocket a couple of times" (Mr Russell, 67y, THR, T2)*
41
42

43 Two participants noted that the wristband casing was clunky and that it rattled. When trying to
44 manage crutches post-surgery, one mentioned that the wearable caught on the crutches.
45

46 Participants felt placing of silhouette sensors in communal areas, (i.e. not in bathrooms or
47 bedrooms) and knowing sensors were not recording video and sound were key system features
48 increasing acceptability. Anonymous data collection and storage within their home, coupled with
49 autonomy to switch the system off, increased acceptability of living with the system.
50

51 *"Only because [son's name] thought they'd be able to recognise us but once I*
52 *explained that you couldn't recognise us, he was happy about it" (Mrs Wilson, 89y,*
53 *TKR, T1)*
54
55

56 *"No, not really. I suppose the sort of cushion is that it's switch off-able if you want to,*
57 *in an absolute, not that I probably won't ever but you know that it's something that*
58 *you've got some control over. So even if there's lots of it about you've got control over*
59 *it, isn't it, to a certain extent" (Mr Baker, 71y, TKR, T1)*
60

1
2
3 Some participants described their concern that the system was capturing information about
4 incorrect performance of exercises or other aspects of post-operative recovery. For instance, they
5 were concerned about their dignity as they moved around their homes unclothed on their return
6 home from hospital.
7

8
9 *“This is silly really but the toilet steps are hard to come from the bedroom and*
10 *obviously because I get hot at night I just sleep without any clothes on and the first*
11 *night I came out it was looking at me and I’d got no clothes on ... that’s*
12 *understandable though isn’t it? Of course it [the home-sensing system] doesn’t see*
13 *does it, but now I don’t worry about it but the first night I was really panicking, I*
14 *rushed back and got a dressing gown.” (Mrs Evans, 85y, THR, T1)*
15

16
17 *“No. The only time I noticed it was when I came home and thought, ‘Hang on a*
18 *minute’ [laughs]. All my private things like washing, going to the loo, these cameras*
19 *are watching me”.* (Mrs Henry, 67y, THR, T2)
20

21 22 **Theme 3 – Pivotal role of social support networks**

23 Leading up to hip or knee replacement, patients attend numerous pre-operative hospital
24 appointments. Coupled with an anxious wait of an unfamiliar operation and unknown post-operative
25 outcomes, patients often draw on additional support from their informal networks. Key significant
26 others involved in care of the present study participants’ felt encouraged at the prospect of taking
27 part in a study that would ‘monitor’ their health and outcomes outside of a hospital environment
28 during this unfamiliar time. Considering their increasing pain and functional decline before hip or
29 knee surgery, many patients make use of their informal social support networks. Such support
30 networks encouraged patients to take part in the research and to live with the SPHERE system once
31 installed.
32

33
34 *“Well my daughter was visiting, and she said it [taking part in the study] was a*
35 *great idea.”* (Mrs Evans, 85y, THR, T1)
36

37
38 *“Yes, I was. I was pleasantly surprised and when I spoke to my daughter in*
39 *London, she said, ‘Oh, that’s great. You’re going to go ahead with this, aren’t*
40 *you, mum?’ I said yes.... Well this was charged because [daughters name] did it*
41 *for me so since I’ve been out of hospital, I didn’t know how to do it, I couldn’t*
42 *remember and [daughter] sort of actually worked it out.”* (Mrs Wilson, 89y, TKR,
43 T1)
44

45 Friends, carers and family members ensured the system was working as the patient went into
46 hospital and that wristbands were charged ready for return. Household members, or grandchildren
47 for those living alone, took on the responsibility of checking the Genie occasionally across the 12 to
48 14 weeks. Family members were also central to addressing any technical issues, this was particularly
49 the case during the immediate post-operative recovery period.
50

51
52 *“And [husbands’ name] charged it [the wristband] up a couple of times ... because the*
53 *battery was going low on it”* (Mrs Harrison, 65y, THR, T2)
54

55 Participants described how grandchildren, younger friends and family members were curious about
56 the system. Participants valued the ability to turn the system off, though none of the participants did
57 so over the course of study participation. Knowing they could turn the system off at any point gave
58 them some control of the system and reassurance that privacy could be maintained. One participant
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3 who rented out a room within her home to the public as a business venture spoke about how she
4 would manage the system.
5

6 *"I had some [queries] last night, actually, is just, 'You may show up as you're coming*
7 *through the front door.' I can't remember whether there was going to be something*
8 *in the hallway or not but if people want to say yes or, 'I don't want to come,' that's*
9 *fine. I'm not seeing it as stopping my business and, actually, for the first few weeks*
10 *I'll shut the calendar off anyway but after that I can get them back"* (Mrs Griffiths,
11 *63y, THR, T1*)
12
13

14 Receiving an additional layer of support and contact from a study research team before and after
15 the operation may have served as reassurance. Providing detailed study information about the
16 various study visits, the technology and the data collected including how the data would be used and
17 stored was also pivotal to patients agreeing to take part.
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19

20 The presence of a system within the home provided intrigue and curiosity for household members,
21 visitors, friends and family. Operating the system became a shared responsibility due to the busy
22 period characterised by reduced mobility, functional limitations and increased pain. Patients
23 depended on informal supportive networks to help maintain the system through the busy trajectory
24 of surgery.
25

26 **DISCUSSION**

27 **Main findings**

28 This study captures patients' experiences of living and interacting with a home monitoring system in
29 the days before and after a major operation. Overall, patients were positive about the installation
30 and presence of the sensors before surgery. The system did not appear to interfere with their
31 preparation for, or recovery from, hip or knee replacement.
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34 However, with an unobtrusive sensing system, comes an increased risk of patients disengaging with
35 the system. In our study, key features of the system maintenance such as charging the wristbands,
36 checking the battery levels of each individual sensors and the main user-interface system (Genie)
37 which itself required charging were subsequently lost at times during participation.
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40 Aesthetics and the location of the SPHERE system's sensors were also key to acceptability of this
41 technology. Initially some expressed concern over damage to surfaces of the walls. After surgery,
42 most patients lived usual day to day activities with very little or no consideration to the sensors once
43 installed. As the patient progressed to the recovery period and returned home from surgery key
44 elements of the system, such as anonymity of the data and being able to turn the system on and off
45 became more salient to the patient if their recovery locations within the house had changed. These
46 features were essential in enabling the patient to retain some control over a system potentially
47 monitoring them and the household in an unfamiliar recovery period.
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49

50 In parallel to the vital support provided to the patient before surgery and in recovery by partners,
51 carers and friends and family members, these informal support networks also assisted the patient
52 with the SPHERE system once installed and throughout the recovery period.
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55 The participatory period was at a time marked with frequent visits from family, friends and carers.
56 Any perceived intrusion or uncertainty about the presence of the system felt was mitigated by the
57 provision of detailed information relating to the sensors, installation procedures and detail about
58 how their data would be used and stored. Such detail combined with an emphasis of anonymisation
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3 of data were key aspects underpinning acceptability and important to understand when perceiving
4 value within a home monitoring system. Such features translate to any long-term acceptability of
5 'lifestyle monitoring' technology, that is, third generation systems that have more complex
6 capabilities and include the measurement, collection and analysis of data in the user's home.[20, 21]
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10 **Findings in relation to existing literature**

11 Our findings build on and reflect an increasing body of research about wearable sensors and systems
12 for home monitoring, in the context of rehabilitation. A key finding in such work has been the
13 importance of end users' full engagement with any home-based system.[22-28] One focus group
14 study conducted by Papi et al. of patients with osteoarthritis discussing the use of prototype wearable
15 technology indicated patients felt that they would not be able to wear the device at night. None of
16 the patients in our study expressed any discomfort of the wearable during the night.[29] This
17 indicates that what patients may feel in a hypothetical situation looking at prototype technology can
18 differ to experiencing this technology under real circumstances, and serves as a strength for
19 undertaking real-world installations of this technology with the intended user groups.
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22 In line with other studies on technology readiness,[30, 31] using any new technology may be
23 enhanced when patients understand why the data is useful and how it may have positive impact on
24 aspects of health. An example might be the use of technology to improve sleep, which is a
25 commonly problem after a hip or knee replacement.[32] Furthermore, people must also see the
26 value of the technology or device to use it.[28] Patients and family members could see value and
27 future benefits of using a home monitoring system contributing to their willingness to be involved in
28 the study.
29
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31 Physical privacy was less of a concern within our study. This finding concords with a systematic
32 review of telecare in home care services and contributes to the debate surrounding ethical issues
33 involved in developing home health monitoring technologies.[28, 33, 34]
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36 Drawing upon informal networks and social support has been previously explored with patients
37 undergoing knee replacement.[35] Although participants valued their independence, most accepted
38 the need to rely on family friends to help them on their journey of having surgery and this included
39 helping them operate the home monitoring system.
40
41

42 Some suggestions from patients when considering the system within a rehabilitation context felt the
43 system could benefit from more engagement. Integrating suggested aspects such as visual feedback,
44 either in real-time or in a periodical report remains important future development work.
45
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47 **Strengths and Weakness of the study**

48 Our use of in-depth qualitative methods provided detailed insight into the experiences and views of
49 patients who were using home health technology around the time of surgery. One-to-one interviews
50 enabled us to explore and probe their views in some depth and our use of thematic analysis allowed
51 us to deepen understanding the factors that underpinned its acceptability. Although our sample was
52 relatively small, we have confidence that we achieved sampling adequacy.[36] We found that no
53 new themes emerged after the 10th participant, indicating that we had achieved data saturation and
54 were able to interview a diverse cross section of participants in terms of age, gender and surgery
55 type. A potential weakness of the study is under-representation of participants across a wide range
56 of socio-economic groups. We noted for instance, that the sample only included individuals who
57 self-identified as white. The sample is reflective of national figures of the proportion of joint
58 replacements amongst different ethnic groups in England.[37] Further research could include more
59 diversity to ensure that the work is more transferable to a range of populations.
60

Conclusions

People about to undergo hip or knee replacement were willing to accept installation of a home sensing system. Participants were able to conduct their preparation for surgery and recovery afterwards, but sometimes forgot to wear the wristband and to keep sensor batteries charged. Informal support networks were key to enabling them to operate the smart home technology before and after surgery. We recommend that development of smart home technology for use at the time of major healthcare intervention consider the roles of other members of a patient's social networks in the successful use of the system. Finally, for healthcare professionals and patients working together, continuous home monitoring may provide a useful picture of activity and function during preparation for and recovery from hip or knee replacement. Further research could identify how best this monitoring could be used to identify when and how additional health or social care might be appropriate.

Contributors RGH, IC and SG conceived the idea of a qualitative exploration. All authors contributed to the study design and participated in the analysis and writing. SG led on the writing and gathered the data. All authors commented on and approved the final version of the manuscript.

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Competing Interests None declared

Patient Consent Obtained

Ethics Approval Ethical approval was received from South West – Central Bristol Research Ethics Committee (17/SW/0121) on 22 June 2017.

Peer Review Not commissioned; externally peer reviewed.

Data Sharing Statement: Anonymised data may be shared via the University of Bristol Research Data Repository. Access to the data will be restricted to ensure that data is only made available to bona fide researchers for ethically approved research projects, on the understanding that confidentiality will be maintained and after a Data Access Agreement has been signed by an institutional signatory.

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3 Tables and Figures
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5 Table 1 – Participant Demographics
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7 Figure 1 – Flow chart of patient through the HEmiSPHERE study
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10 Figure 2 – Participant Recruitment
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Table 1 – Participant Demographics

Pseudonym	Age at first interview (years)	Gender	Total Hip / Total Knee Replacement (THR/TKR)	Co-habitation status
Mr Hayes	70	Male	THR	Lives with spouse
Mrs Henry	67	Female	THR	Lives with spouse
Mr Price	85	Male	THR	Lives with spouse
Mrs Evans	85	Female	THR	Lives alone
Mr Connell	67	Male	TKR	Lives with spouse
Mrs Griffiths	63	Female	THR	Lives with son and daughter in law*
Mrs Wilson	89	Female	TKR	Lives alone
Mrs Murray	71	Female	THR	Lives alone
Mrs Bailey	73	Female	THR	Lives with partner
Mrs Harrison	65	Female	THR	Lives with spouse and son*
Mrs Thompson	75	Female	THR	Lives with spouse
Mr Baker	71	Male	TKR	Lives with spouse

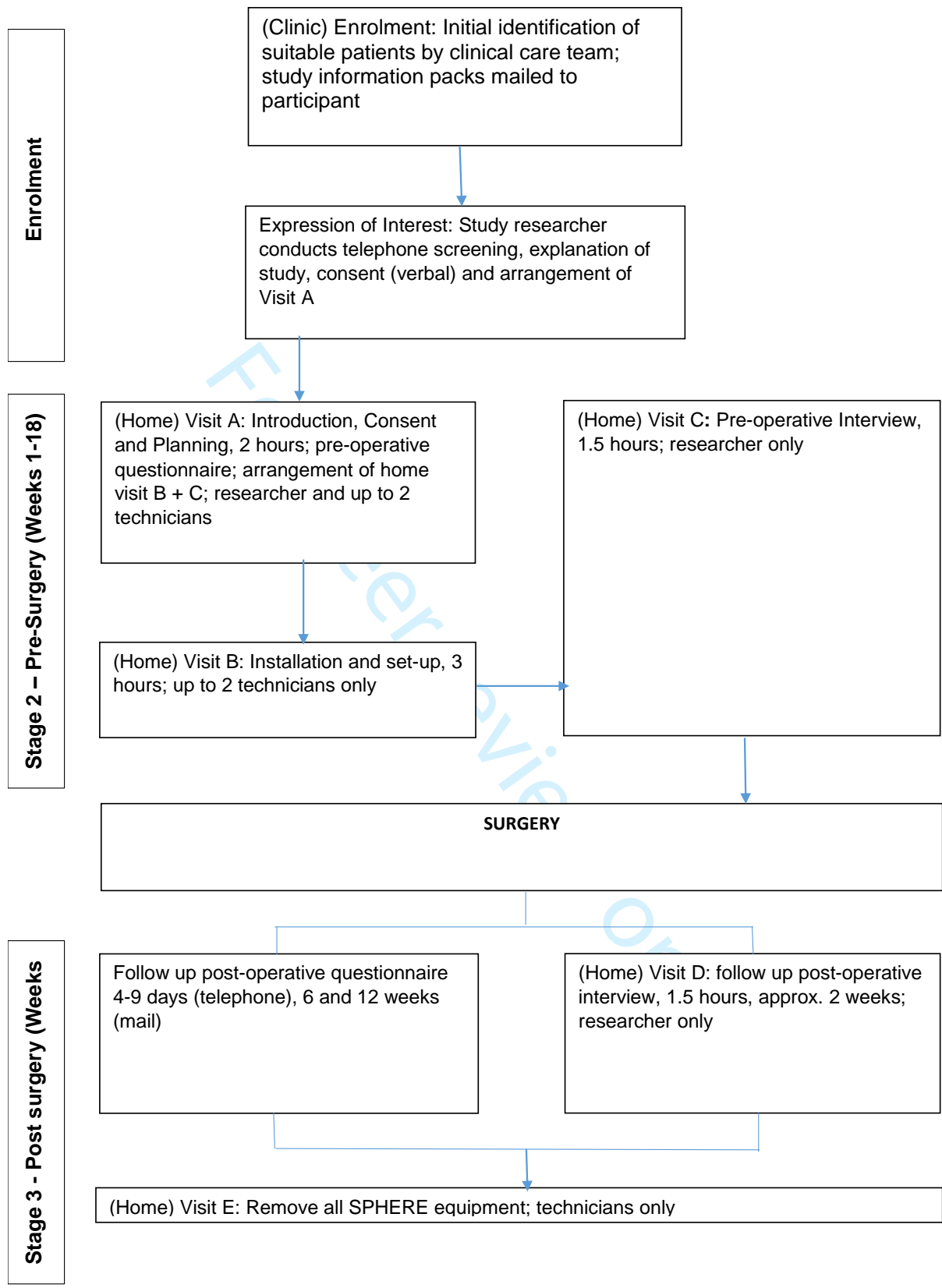
*adult household member

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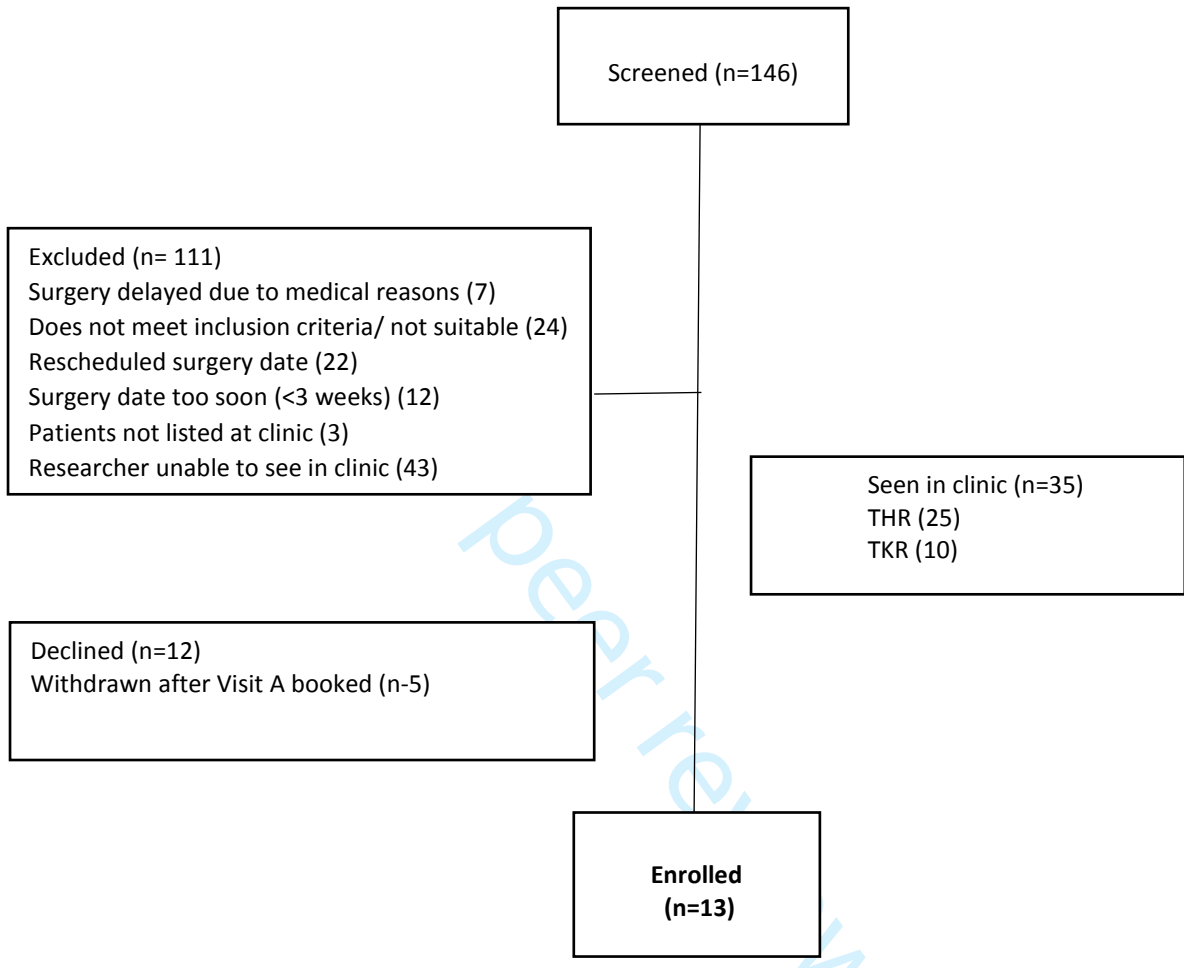
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COREC Checklist

Page Number Text and Comments

- 1 4 Interviews were conducted by an experienced qualitative researcher (SG) with all patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint 2, T2) surgery.
- 2 4 Interviews were conducted by an experienced qualitative researcher (SG)
- 3 4 Interviews were conducted by an experienced qualitative researcher (SG)
- 4 4 Interviews were conducted by an experienced qualitative researcher (SG)
- 5 4 Interviews were conducted by an experienced qualitative researcher (SG) with all patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint 2, T2) surgery.
- 6 5 All participants provided written consent before taking part during the initial planning home visit.
- 7 5 Participants and interviewer were not known to each other prior to study commencement; Participants and interviewer were not known to each other prior to study commencement.
- 8 4,5 Background of the interviewer was not disclosed to participants;
- 9 5 Background of the interviewer was not disclosed to participants;
- 10 4,5 13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled and enrolled onto the study.
- 11 4 Recruitment took place initially by postal methods, mailed an information pack (invitation letter, information booklet detailing purposes of the study, description including images of the sensor system, installation procedures and detailed information about how their data would be used and stored and reply slip). Participants returning the reply slip were contacted by the study researcher (SG) and invited to the study. Patients were also screened for eligibility at their pre-operative consultation by their treating consultant and then approached in clinic by a researcher to explain the study, provide an information booklet and invited to study.
- 12 5, Figure 2 13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled and enrolled onto the study.
- 13 5, Figure 2 Of the 35 patients seen in clinic, 12 declined to participate (concerns of living alone and managing study requirements, too burdensome, family not keen) 5 withdrew after booking Visit A (i.e. verbal agreement only). Of the 13 finally enrolled onto the study, 3 were recruited by post and one by radio advertisement. Further details of recruitment are reported in Figure 2.

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- 14 4 All data collection took place within the home; Each interview took place in the participant's home.
- 15 5 On occasion, a household member was present.
- 16 4, Table 1 13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled and enrolled onto the study. Participants were aged between 63 and 89 years and comprised 5 men and 8 women, with 10 undergoing hip replacement and 3 undergoing knee replacement. Demographic information about the 13 participants is displayed in Table 1. All names are pseudonyms.
- 17 1 supplements 2-5 All participants' names were replaced with pseudonyms, and identifiable information was removed. Interviews lasted between 45 and 60 minutes and open-ended questions followed topic guides (Box 1).
- 18 4 Interviews were conducted by an experienced qualitative researcher (SG) with all patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint 2, T2) surgery.
- 19 5 Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[16] Supplementary field notes were taken after the interview.
- 20 5 Supplementary field notes were taken after the interview.
- 21 5 Interviews lasted between 45 and 60 minutes
- 22 12 We found that no new themes emerged after the 10th participant, indicating that we had achieved data saturation and were able to interview a diverse cross section of participants in terms of age, gender and surgery type
- 23 5 We did not return transcripts to participants but some of the preliminary results were discussed with the PPI group
- 24 5, 13 Codes were checked for consistency and validation by a second experienced researcher in the department, and the study team (SG, RGH, MW, AB); We would like to acknowledge Dr Abir Ghorayeb for double coding a portion of the transcripts and to all the patients participating in the study.
- 25 No We do not supply a coding tree, this can be requested to the authors
- 26 5
Using thematic analysis [17] the researcher (SG) read and re-read the data to ensure familiarity, coding inductively before sorting coded data into themes. [15]
- 27 5 Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[16]

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28 5 We did not return transcripts to participants but some of the preliminary results were
discussed with the PPI group

29 6 We include illustrative quotations from participants, all names are pseudonyms and we
indicate total hip replacement (THR) or total knee replacement (TKR) and timepoint (T1
or T2) next to each quotation.

30 11 to 13 Yes

31 6 to 11 Yes

32 6 to 11 Only the three overarching themes are reported

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BMJ Open

Home health monitoring around the time of surgery: a qualitative study of patients' experiences before and after joint replacement

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Manuscript ID	bmjopen-2019-032205.R1
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Date Submitted by the Author:	24-Sep-2019
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Primary Subject Heading:	Qualitative research
Secondary Subject Heading:	Surgery
Keywords:	Orthopaedic & trauma surgery < SURGERY, Hip < ORTHOPAEDIC & TRAUMA SURGERY, Knee < ORTHOPAEDIC & TRAUMA SURGERY, QUALITATIVE RESEARCH

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Manuscripts

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6 **Home health monitoring around the time of surgery: a qualitative study of patients' experiences**
7 **before and after joint replacement**

8
9 Authors: Grant S¹, Blom AW^{1,3}, Craddock I², Whitehouse MR^{1,3}, Gooberman-Hill R^{1,3}

10
11 ¹ Musculoskeletal Research Unit, Translational Health Sciences, Bristol Medical School, University of
12 Bristol, Learning and Research Building, Level 1, Southmead Hospital, Southmead, Bristol, BS10 5NB,
13 UK

14 ² SPHERE-IRC, Digital Health, 1 Cathedral Square, Trinity Street, Bristol, BS1 5DD, UK

15 ³ National Institute for Health Research Bristol Biomedical Research Centre, University Hospitals
16 Bristol NHS Foundation Trust and University of Bristol, UK
17

18
19 Corresponding author: Dr Sabrina Grant, sabrina.grant@worc.ac.uk, +44 1905 542648

20
21 Keywords:

22 home monitoring, hip, knee, qualitative, orthopaedic
23

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Abstract

Objectives: Hip and knee replacements are common major elective surgical interventions with over 200,000 performed annually in the UK. Not all patients achieve optimal outcomes or experience problems or delays in recovery. The number of patients needing these operations are set to increase and routine clinical monitoring is time and resource consuming for patients and healthcare providers, therefore innovative evaluation of surgical outcomes are needed. The aim of this qualitative study was to capture the patient experience of living with a novel home monitoring sensing system during the period around joint replacement.

Setting: One secondary care hospital in the South West, UK

Participants: 13 patients, (8 female, 63-89y) undergoing total hip or knee replacement enrolled into the study

Design: Qualitative study with thematic analysis. The system remained in situ for up to 12 weeks after their surgery and comprised a group of low powered sensors monitoring the environment (temperature, light and humidity) and activity of people within the home. Patients were interviewed at two timepoints: before and after surgery. Interviews explored views about living with the technology, its acceptability as well as attitudes towards health technology.

Results: Three main themes emerged: installation of home sensing technology on the journey to surgery; the home space and defining unobtrusiveness and pivotal role of social support networks

Conclusions: Patients who agreed to the technology found living with it acceptable. A home sensing system that monitors the environment and activity of the people in the home could provide an innovative way of assessing patients' surgical outcomes. At a time, characterised by reduced mobility, functional limitations and increased pain, patients in this study relied on informal and formal supportive networks to help maintain the system through the busy trajectory of the perioperative period.

Strengths and limitations of this study

- In-depth one-to-one interviews provided insight into patients' real experiences and views as they lived with the technology in their own homes
- Although the sample size was small, lacked ethnic diversity and only included people willing to have technology installed in their homes, there was good diversity in age and gender and some diversity in patients undergoing hip and knee replacement
- Use of thematic analysis enabled robust analysis of data, including focus on the acceptability of the technology in real health-related circumstances.

INTRODUCTION

For people living with osteoarthritis or other forms of joint disease that has not responded to non-operative treatments, total hip or knee replacement may be provided. Numbers of these procedures are rising and continue to do so as the population ages: in 2017 alone, 91,698 primary total hip and 102,177 knee replacements were performed in England, Wales, Northern Ireland and the Isle of Man.[1, 2] Having a total hip or knee replaced involves removal of the affected joint and its replacement with prosthetic implants.

Longitudinal cohort studies have shown that outcomes for hip and knee replacement vary with around 20% of knee and 9% of hip replacement patients reporting long term pain.[3] The length of stay following hip and knee replacements has declined over time[4] and enhanced recovery pathways can further reduce length of stay.[5] Brander et al. reported one in eight patients still had substantial pain one year after surgery despite 'well-fitting' and functioning implants.[6] Wylde et al. found that two years following surgery, 11% of patients thought function was the same or worse than it was pre-operatively.[7]

Information technology is already woven into many aspects of patients' lives. In a health context, technology may provide the possibility for older adults with chronic conditions and complex needs to remain at home and maintain an acceptable quality of life.[8] Technologies for use at home may include 'wearable sensors to detect changes in vital signs,[9] functional monitoring, emergency fall detection[10, 11]and cognitive and sensory assistance.[12] For patients in rehabilitation following hip or knee surgery, greater use of technology (such as video-conferencing and remote monitoring) have been suggested as solutions to improving the quality of care and optimising short and long term patient outcomes.[13, 14] A review of research up to 2017 focusing on the use of technology in the home, remote monitoring systems and design of better environments for older people[15] indicated that despite an increase in studies focusing on local services and equipment that are patient-centred in design, many clinicians may be reluctant to accept change due to a lack of education in this emerging field and how it affects their patients. Others have highlighted the importance of research to understand the needs and experiences of older people and how these technologies are used. Evidence from studies about use of technology can be used to inform their improvement to technology.[16]

To ensure technologies are developed in ways that make them fit for purpose and acceptable, there is a need to understand and characterise the views of the people who have experience of using them. The Hip and KnEe Study of a Sensor Platform of Healthcare in a Residential Environment (HEmiSPHERE) aimed to assess the acceptability of home monitoring system for patients in the NHS who were undergoing hip or knee replacement.[17] We describe qualitative research within HEmiSPHERE that explored and characterised patients' experiences of this technology.

METHODS

The HEmiSPHERE study embedded within a broader project: 'A Sensor Platform of Healthcare in a Residential Environment' (SPHERE) is an interdisciplinary research project that has developed sensor technology to monitor home environments.[18] The SPHERE system comprises a group of low power sensors that can continuously measure anonymised, time-stamped information about the home (e.g. temperature, humidity), this includes appliance monitors to capture use of electricity, and sensors to collect information about movement through silhouettes (body outlines). The system also includes a wearable wristband, worn by the patient, collecting accelerometry information about movement within their home. Collectively the system can measure location, activity, speed and

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2
3 frequency of 'sit to stand' transitions as a surrogate marker for extent of movement. Installing the
4 system requires up to four hours of technicians' time and the system requires minimal input from
5 individuals in their homes. Patients and household members operated the system via a tablet
6 computer that contained an operating function to pause the monitoring system and to check the
7 battery levels of the devices. As such it is a 'passive' monitoring system.[15] To date, the SPHERE
8 sensor system has been installed in a total of 52 homes in the South West of England, of which 13
9 were homes of people undergoing hip or knee replacement and who comprise the sample for this
10 study.[18]
11

12 13 **Sample**

14 13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled
15 and enrolled onto the study. As recruitment progressed the sample was reviewed to assess if there
16 was diversity in age and gender, as there was reasonable diversity, we did not adjust sampling
17 processes as the study progressed. Participants were aged between 63 and 89 years and comprised
18 5 men and 8 women, with 10 undergoing hip replacement and 3 undergoing knee replacement.
19 Demographic information about the 13 participants is displayed in Table 1. All names are
20 pseudonyms.
21

22
23 Insert Table 1 – Participant Demographics
24

25 26 **Recruitment**

27 All participants provided written consent before taking part during the initial planning home visit.
28 Patients placed on the waiting list for a total hip or knee replacement were identified and recruited
29 from one orthopaedic centre in the South West of England. Potential participants were mailed an
30 information pack (invitation letter, information booklet detailing purposes of the study, description
31 including images of the sensor system, installation procedures and detailed information about how
32 their data would be used and stored and reply slip). Potential participants who had returned the
33 reply slip were contacted by the study researcher (SG) and invited to discuss the study. Patients
34 were also screened for eligibility at their pre-operative consultation by their treating consultant and
35 then approached in clinic by a researcher to explain the study, provide an information booklet and
36 invite them to take part. To widen the reach of patients undergoing joint replacement in the NHS the
37 study, parallel to recruitment, the study was also discussed with an interviewer on a local radio
38 health show broadcast.
39

40 41 **Eligibility Criteria**

42 Adults who could read and understand English. As the study focused on the views of people
43 undergoing hip or knee replacement for osteoarthritis, we designed the study consent procedures
44 for an adult population. Participants were excluded if children (16 and under) lived in the patient's
45 home.
46

47 48 **Data collection and analysis**

49 All data collection took place within the participants' own homes. The SPHERE system was installed
50 approximately two weeks before the patient's surgery date (Figure 1) and continued to monitor the
51 household before, during and up to twelve weeks after surgery.
52

53 [Insert Figure 1 – Flow chart of patient through the HEmiSPHERE study]
54

55 Interviews were conducted by an experienced qualitative researcher, who had a background in
56 psychology (SG), with all patients before surgery (Time-Point 1, T1) and approximately two weeks
57 after surgery (Timepoint 2, T2). The background of the interviewer was not disclosed to participants
58 as the collection and analysis of the data was conducted with impartiality and openness to any type
59
60

of findings. In-depth interviews using probes and prompts provided understanding of lived experiences.[19] Each interview took place in the participant's home. On occasion, a household member was present. Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[20] Supplementary field notes were taken after the interview. All participants' names were replaced with pseudonyms, and identifiable information was removed. Interviews lasted between 45 and 60 minutes and open-ended questions followed topic guides (Box 1). Participants and interviewer were not known to each other before study commencement.

Box 1 Topic Guides

Pre-surgery (Timepoint 1; T1)

- Route to referral for surgery
- People living in the household
- Previous experience of health technology (home, wearable, apps)
- Current experience and future expectations of mobility and function
- Preparations in the household for surgery

Post-surgery (Timepoint 2; T2)

- Experience of aftercare post-surgery
- Experience of living with SPHERE technology
- Ask about the adequacy of information received about SPHERE technology
- Explore how initial expectations of living with the SPHERE technology compared to the experience

Each interview at T1 began with an introduction to the aims of the interview, and a discussion of their journey into joint replacement, (route to referral), views about the SPHERE sensor system, household constitution and health technology usage. Interviews after surgery explored care after surgery and living with the SPHERE sensor system. Using thematic analysis [21] the researcher (SG) read and re-read the data to ensure familiarity, coding inductively before sorting coded data into themes.(Supplementary file 1)[19] Codes were checked for consistency and validation by a second experienced researcher in the department, and the study team (SG, RGH, MW, AB).

We consulted a patient involvement group (described below) about the development and analyses of topic guides and used established criteria to inform our reporting of the qualitative study.[22]

Patient and Public Involvement

This study was developed in collaboration with the Patient Experience Partnership in Research, (PEP-R).[23] PEP-R is a patient involvement group, most of whom have had joint replacements, all of whom have had experiences of long term pain, some after knee replacement. PEP-R provide input into research prioritisation and provided specific input into the study design, including the materials such as recruitment documentation and interview topic guide. They also viewed and commented on feedback to participants. SPHERE's professional advisory group were consulted on the project as a whole and the design of study materials.

RESULTS

Of the 35 patients seen in clinic, 12 declined to participate (concerns of living alone and managing study requirements, too burdensome, family not keen) and 5 patients' and household members did not continue to full, written consent after providing their initial verbal agreement at booking Visit A.

The five participants did not progress to provision of full, written consent for varying reasons. These were that not all members of their household provided full agreement; verbal agreement was not followed by full formal consent; worries about surgery, and other illnesses. Of the 13 finally enrolled onto and completing the study, 3 were recruited by post and one contacted the study researcher after hearing the radio broadcast. Further details of recruitment are reported in Figure 2.

[Insert Figure 2 Participant recruitment]

We identified three main themes relating to acceptability of home monitoring technology: installation of home sensing technology on the journey to surgery, the home space and defining unobtrusiveness and pivotal role of social support networks. We include illustrative quotations from participants, all names are pseudonyms and we indicate total hip replacement (THR) or total knee replacement (TKR) and timepoint (T1 or T2) next to each quotation.

Theme 1 – Installation of ‘home sensing technology’ on the journey to surgery

On route to having hip or knee replacement, a patient can expect to receive numerous letters to attend appointments with healthcare professionals (HCPs) before the day of their operation. Patients may also make plans with carers, friends or relatives about how best to recover and receive support in the weeks after surgery. This presents a critical time when anticipation of surgery may result in a period of heightened anxiety. We wanted to capture patients’ experiences of being recruited and having this SPHERE sensor installed during this peak activity period.

All our patients were accepting of our approaches and contents of the information booklet.

“Oh, it [study information booklet] was fine. I read it through, took it in, it seemed to answer anything I wanted to know” (Mrs Wilson, 89y, TKR, T1)

“It [study visit] was okay, no it was plenty enough. Everybody’s been very careful to explain every step of the way” (Mr Hayes, 70y, THR, T1)

Providing a separate study information booklet tailored to household members gave additional assurance for others living within the household from a different perspective to the patient.

“No, I think it was fine and actually after you came the last time I said to [family members’ names] ‘How was that? Do you want to ask me any questions and they said, ‘No, no, no. That was fine.’ It was fine and then I saw them looking through the leaflet again the other night, so I think they’re quite happy as well” (Mrs Griffiths, 63y, THR, T1)

In dealing with the complex detail of the study, many felt the study information booklet and SPHERE user guide were useful to refer to.

“Sometimes when you’re talking about different things to do with this thing [the SPHERE system], you’re listening but you’re not really taking it in. You then think, ‘What did she say about so and so?’ and then you flip through whatever” (Mr Russell, 67y, THR, T2)

Patients and household members were shown the actual sensors (as opposed to images) and asked to try on the wristband at the first visit. This helped them to understand the system in context of their own home.

“Well see I’m not very good at that sort of thing [technology] so what you’ve shown me is enough, I mean I basically know what’s going on” (Mrs Evans, 85y, THR, T2)

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3 Patients were asked to remember some information about how to use the system. Some people
4 found this hard to recall or to act upon. For instance, remembering to charge the tablet could be
5 hard.
6

7 *"I have only charged it the once I think that I can remember ... I haven't bothered*
8 *switching it on and off" (Mr Connell, 67y, TKR, T1)*
9

10 Participants described altruistic reasons for taking part in the study, that is they were willing to take
11 part in the research to provide benefit to others in the future.
12

13
14 *"I thought well it [participation in the study] would be a bit intrusive, but you know I*
15 *think that everybody should do their bit to help the medical science to keep moving*
16 *forward so I just thought I you know I ought to agree" (Mr Hayes, 70y, THR, T1)*
17

18 *"Well I hope it will help somebody because you know it's, it probably won't help me*
19 *will it, I can't see how it can help me, but I can see it helping others" (Mrs Evans, 85y,*
20 *THR, T1)*
21

22
23 Participants did not make much use of existing health technologies such as blood pressure monitors.
24 Participants nonetheless could think of reasons how this technology could help other patients having
25 surgery.
26

27 *"I thought it [participation in the study] was a good idea. I did. If it's going to help*
28 *patients to recovery, it should be good. I'd hope it would help people who are having*
29 *operations like this" (Mr Price, 85y, THR, T1)*
30

31 Despite their preparation for major surgery, participants did not mind the level of contact required
32 for this study before and after the operation. In the event of technical problems, participants felt
33 they were dealt with satisfactorily but sometimes would have preferred a more rapid response.
34

35
36 *"I emailed but it was a Sunday afternoon and they [friends] were coming in the evening*
37 *but I couldn't get into the thing [Genie] as I had forgot the passcode and obviously I*
38 *didn't hear back until the following day when actually I rang again because nobody*
39 *responded to the email on the Monday but I rang and spoke to the young lady in your*
40 *office eventually. There was a little communication gap I think was all it was really*
41 *anyway, but that was fine. It was all, once I got the code I was fine" (Mr Hayes, 70y,*
42 *TKR, T1)*
43

44
45 Participants were accepting of having to understand and comply with detailed information and study
46 procedures despite a busy period in preparation for surgery. Thinking about the benefits for patients
47 in the future as a result of their participation in the study appeared to be a primary motivator to
48 allow this technology to be fitted and monitor their activity within the home.
49

50 **Theme 2 – The home space and defining unobtrusiveness**

51 Use of the home space before and after surgery was dynamic. Before the SPHERE system was
52 installed, participants were provided with detailed floorplans developed by the SPHERE team. These
53 mapped areas of high traffic, where they spent most or least time. For obvious reasons, the protocol
54 omitted any installation of silhouette sensors in bathrooms or bedrooms.
55

56
57 Participants described the use of their home reflecting on the use of the space which was often
58 influenced by seasonal variations.
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“When he’s [husband] I’m here [in lounge] and also, it’s warmer in there. So when, you know, on a cold day it’s warmer in there so we found ourselves sitting in there more ... when you asked me I thought, ‘I’d probably stay here most of the time’. It’s only afterwards you think, ‘Oh, I do go in there a lot” (Mrs Thompson, 75y, THR, T2)

The journey after surgery sometimes gave a different perspective on the use of the downstairs space. For instance, positioning themselves in the lounge or conservatory to a preferred chair where they felt most comfortable.

One participant, Mrs Henry, described the downstairs becoming the ideal place to wash, bathe and dress. In this case the study protocol therefore required the removal of all silhouette sensors from the downstairs level of her house. Since there were also some wireless connectivity problems in the property, it was agreed with the participant that, to save a future visit, it would be sensible to remove all the other sensors at the same time. Mrs Henry remained in the study and continued to complete the study paperwork.

“I’m still getting washed and dressed at the table there because we’ve only got a tiny bathroom and it was not easy, it’s not easy in there” (Mrs Henry, 67y, THR, T2)

Anticipating installation of the SPHERE system in the house, some participants expressed concerns about internal damage to wall surfaces within the rooms. Although the sensor data network was wireless some noted that the necessary power supply cabling for some of the sensors did not match their expectations, which they had expected to be entirely ‘wireless’.

“Well I did say to you before that I am amazed that they’re not Wi-Fi or wireless. Why do they have to be cabled, I do not understand but there you are. I’m sure your technicians would know a lot more than me, it’s pretty unsightly having cabling running up walls, which it is in the lounge, in the back room and in here. You know, makes what is fairly obvious even more”. (Mr Hayes, 70y, TKR, T1)

Despite concerns about aesthetics, most felt they did not have to pay much attention to the system on a day-to-day basis. Participants were given the choice to switch the system off when they went into hospital. All decided to keep the system running during this time. Some participants wondered if they should be interacting more with the Genie, a tablet provided to the participant, which through an installed app could control the whole system, pause or delete data within certain time frames.

“Sorry, just while I think about it, so all I’m doing is just looking to see when this needs charging? I’m not supposed to use the iPad for anything else? It would be nice if people could use it while they’re stuck at home? It might be an encouragement for people to do the study ... I don’t know. I don’t know what the take-up is of the study, whether it would be an extra thing that people could use it for something, I don’t know. But an app could be installed on it just to do something.” [Mrs Thompson, 75y, THR, T2]

“It was a bit, I sort of wasn’t quite sure what I was supposed to be doing but I’d used it just to check my batteries mainly.” [Mrs Harrison, 65y, THR, T2]

In the immediate post-operative recovery period, some patients experienced discomfort and post-operative pain particularly in the area near the surgical wound. Adapting to the recovery phase

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3 within the household, for instance working out how to position furniture to enable them to move
4 was challenging for many, particularly for patients living alone. With very little interaction with the
5 system day-to-day and concentration on recovery, some participants described how they
6 occasionally forgot to wear the wristband such as after showering or when leaving the house. Some
7 participants also described how they had not checked battery levels or had forgotten to put the
8 wristband back on after showering. They suggested further improvements to the system such as
9 adding warning lights on the wristband or for warnings to be indicated clearly on the study
10 information.
11

12
13 *“Maybe it should be in the brochure or somewhere in big letters “wear this all the*
14 *time, including when you are going to bed”. You just think that it’s useful for*
15 *recording when I walk from room to room and as going up the stairs. Because there is*
16 *no recording device in the bedroom, you don’t think but you obviously connect the*
17 *wristband with one of those. Downstairs is where I should be wearing it. I certainly*
18 *take it off before I even climbs the stairs, unless I’m going to the toilet”. (Mr Russell,*
19 *67y, THR, T2)*
20

21
22 *“Even if it could be on a sticker on the front. ‘Wear this everywhere, apart from when*
23 *you’re in the shower’ that would be good and then I would wear it, especially now, and*
24 *wear it to bed. It’s what people see and that’s what they do. It doesn’t matter about the*
25 *other thing about charging it up because they’ll eventually think, ‘It ought to be charged*
26 *by now” (Mr Connell, 67y, TKR, T2)*
27

28
29 *“Yeah yeah and it’s almost that said oh you are on that but flashed up, I don’t know, like*
30 *a green light or something or your battery’s going or something’s going on it that*
31 *shouldn’t it might be a good idea yeah” (Mrs Evans, 85y, THR, T2)*
32

33 Of the range of sensors within the SPHERE system, patients’ experiences of the wearable wristband
34 varied. Most patients felt the wristband was acceptable.
35

36
37 *“Do you know what, I thought I’d find it annoying. I really did think I’d find it annoying*
38 *and that I would have to, because I don’t even like to wear a watch, I do have a medical*
39 *alert and I keep that on but I don’t even like wearing a wristwatch particularly. I like to*
40 *have my wrists free. Maybe because I’m not doing a lot of housework and washing, I’m*
41 *not getting in the garden digging, maybe I’m not so aware of it because I’m not*
42 *washing my hands a lot. So I sort of forgot about it, which surprised me a bit. So that’s*
43 *quite nice”. (Mrs Griffiths, 63y, THR, T2)*
44

45 However, some participants found the wristband inconvenient and sometimes took it off because of
46 this.
47

48
49 *“Yeah, it’s the left hand as well and I’m not very good with my hands. It would be*
50 *better if it was a clip on or something like that. You could put it in there somewhere*
51 *rather than strapping it on your wrist because it is uncomfortable as well. It’s not*
52 *uncomfortable as being annoying, sore or anything like that. It’s just an inconvenience*
53 *... I’ve put it in my pocket a couple of times” (Mr Russell, 67y, THR, T2)*
54

55 Two participants noted that the wristband casing was clunky and that it rattled. When trying to
56 manage crutches post-surgery, one mentioned that the wearable caught on the crutches.
57

58 Participants felt placing of silhouette sensors in communal areas, (i.e. not in bathrooms or
59 bedrooms) and knowing sensors were not recording video and sound were key system features
60

1
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3 increasing acceptability. Anonymous data collection and storage within their home, coupled with
4 autonomy to switch the system off, increased acceptability of living with the system.
5

6
7 *"Only because [son's name] thought they'd be able to recognise us but once I*
8 *explained that you couldn't recognise us, he was happy about it"* (Mrs Wilson, 89y,
9 *TKR, T1)*

10
11 *"No, not really. I suppose the sort of cushion is that it's switch off-able if you want to,*
12 *in an absolute, not that I probably won't ever but you know that it's something that*
13 *you've got some control over. So even if there's lots of it about you've got control over*
14 *it, isn't it, to a certain extent"* (Mr Baker, 71y, TKR, T1)
15

16 Some participants described their concern that the system was capturing information about
17 incorrect performance of exercises or other aspects of post-operative recovery. For instance, they
18 were concerned about their dignity as they moved around their homes unclothed on their return
19 home from hospital.
20

21
22 *"This is silly really but the toilet steps are hard to come from the bedroom and*
23 *obviously because I get hot at night I just sleep without any clothes on and the first*
24 *night I came out it was looking at me and I'd got no clothes on ... that's*
25 *understandable though isn't it? Of course it [the home-sensing system] doesn't see*
26 *does it, but now I don't worry about it but the first night I was really panicking, I*
27 *rushed back and got a dressing gown."* (Mrs Evans, 85y, THR, T1)
28

29
30 *"No. The only time I noticed it was when I came home and thought, 'Hang on a*
31 *minute' [laughs]. All my private things like washing, going to the loo, these cameras*
32 *are watching me".* (Mrs Henry, 67y, THR, T2)
33

34 35 **Theme 3 – Pivotal role of social support networks**

36 Leading up to hip or knee replacement, patients attend numerous pre-operative hospital
37 appointments. Coupled with an anxious wait of an unfamiliar operation and unknown post-operative
38 outcomes, patients often draw on additional support from their informal networks. Whilst
39 participants were fully informed that the system did not provide a realtime monitoring function,
40 household members nonetheless felt encouraged at the prospect of taking part in a study that
41 would 'monitor' their health and outcomes outside of a hospital environment during this unfamiliar
42 time. Considering their increasing pain and functional decline before hip or knee surgery, many
43 patients make use of their informal social support networks. Such support networks encouraged
44 patients to take part in the research and to live with the SPHERE system once installed.
45

46
47 *"Well my daughter was visiting, and she said it [taking part in the study] was a*
48 *great idea."* (Mrs Evans, 85y, THR, T1)
49

50
51 *"Yes, I was. I was pleasantly surprised and when I spoke to my daughter in*
52 *London, she said, 'Oh, that's great. You're going to go ahead with this, aren't*
53 *you, mum?' I said yes.... Well this was charged because [daughters name] did it*
54 *for me so since I've been out of hospital, I didn't know how to do it, I couldn't*
55 *remember and [daughter] sort of actually worked it out."* (Mrs Wilson, 89y, TKR,
56 *T1)*
57

58 Friends, carers and family members ensured the system was working as the patient went into
59 hospital and that wristbands were charged ready for return. Household members, or grandchildren
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3 for those living alone, took on the responsibility of checking the Genie occasionally across the 12 to
4 14 weeks. Family members were also central to addressing any technical issues, this was particularly
5 the case during the immediate post-operative recovery period.
6

7
8 *“And [husbands’ name] charged it [the wristband] up a couple of times ... because the*
9 *battery was going low on it” (Mrs Harrison, 65y, THR, T2)*

10
11 Participants described how grandchildren, younger friends and family members were curious about
12 the system. Participants valued the ability to turn the system off, though none of the participants did
13 so over the course of study participation. Knowing they could turn the system off at any point gave
14 them some control of the system and reassurance that privacy could be maintained. One participant
15 who rented out a room within her home to the public as a business venture spoke about how she
16 would manage the system.
17

18
19 *“I had some [queries] last night, actually, is just, ‘You may show up as you’re coming*
20 *through the front door.’ I can’t remember whether there was going to be something*
21 *in the hallway or not but if people want to say yes or, ‘I don’t want to come,’ that’s*
22 *fine. I’m not seeing it as stopping my business and, actually, for the first few weeks*
23 *I’ll shut the calendar off anyway but after that I can get them back” (Mrs Griffiths,*
24 *63y, THR, T1)*
25

26
27 Receiving an additional layer of support and contact from a study research team before and after
28 the operation may have served as reassurance. Providing detailed study information about the
29 various study visits, the technology and the data collected including how the data would be used and
30 stored was also pivotal to patients agreeing to take part.
31

32
33 The presence of a system within the home provided intrigue and curiosity for household members,
34 visitors, friends and family. Operating the system became a shared responsibility due to the busy
35 period characterised by reduced mobility, functional limitations and increased pain. Patients
36 depended on informal supportive networks to help maintain the system through the busy trajectory
37 of surgery.
38

39 **DISCUSSION**

40 **Main findings**

41
42 This study captures patients’ experiences of living and interacting with a home monitoring system in
43 the days before and after a major operation. Overall, patients were positive about the installation
44 and presence of the sensors before surgery. The system did not appear to interfere with their
45 preparation for, or recovery from, hip or knee replacement.
46

47
48 However, with an unobtrusive sensing system, comes an increased risk of patients disengaging with
49 the system. In our study, key features of the system maintenance such as charging the wristbands,
50 checking the battery levels of each individual sensors and the main user-interface system (Genie)
51 which itself required charging were subsequently lost at times during participation.
52

53
54 Aesthetics and the location of the SPHERE system’s sensors were also key to acceptability of this
55 technology. Initially some expressed concern over damage to surfaces of the walls. After surgery,
56 most patients lived usual day to day activities with very little or no consideration to the sensors once
57 installed. As the patient progressed to the recovery period and returned home from surgery key
58 elements of the system, such as anonymity of the data and being able to turn the system on and off
59 became more salient to the patient if their recovery locations within the house had changed. These
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3 features were essential in enabling the patient to retain some control over a system potentially
4 monitoring them and the household in an unfamiliar recovery period.
5

6 In parallel to the vital support provided to the patient before surgery and in recovery by partners,
7 carers and friends and family members, these informal support networks also assisted the patient
8 with the SPHERE system once installed and throughout the recovery period.
9

10
11 The period of study participation was at a time marked by frequent visits from family, friends and
12 carers. Any perceived intrusion or uncertainty about the presence of the system felt was mitigated
13 by the provision of detailed information relating to the sensors, installation procedures and detail
14 about how their data would be used and stored. Such detail combined with an emphasis of
15 anonymisation of data were key aspects underpinning acceptability and important to understand
16 when perceiving value within a home monitoring system. Such features translate to any long-term
17 acceptability of 'lifestyle monitoring' technology, that is, third generation systems that have more
18 complex capabilities and include the measurement, collection and analysis of data in the user's
19 home.[24, 25]
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23 **Findings in relation to existing literature**

24 Our findings build on and reflect an increasing body of research about wearable sensors and systems
25 for home monitoring, in the context of rehabilitation. A key finding in such work has been the
26 importance of end users' full engagement with any home-based system.[26-32] One focus group
27 study conducted by Papi et al. of patients with osteoarthritis discussing the use of prototype wearable
28 technology indicated patients felt that they would not be able to wear the device at night. None of
29 the patients in our study expressed any discomfort of the wearable during the night. This indicates
30 that what patients may feel in a hypothetical situation looking at prototype technology can differ to
31 experiencing this technology under real circumstances and serves as a strength for undertaking real-
32 world installations of this technology with the intended user groups.
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35 In line with other studies on technology readiness,[33, 34] using any new technology may be
36 enhanced when patients understand why the data is useful and how it may have positive impact on
37 aspects of health. An example might be the use of technology to improve sleep, which is a
38 commonly problem after a hip or knee replacement.[35] Furthermore, people must also see the
39 value of the technology or device to use it.[32] Patients and family members could see value and
40 future benefits of using a home monitoring system contributing to their willingness to be involved in
41 the study.
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44 Participants generally felt that their own privacy was appropriately addressed by the study design
45 but expressed more concerns relating to the privacy of friends and family entering the home, though
46 these were mitigated by the option for participants to switch the system off at any time. Where, as
47 here, sensor systems are designed to be respectful of the higher expectation of privacy in rooms
48 such as bedrooms and bathrooms, studies need to consider whether patients might regularly need
49 to wash or dress in other rooms as a consequence of their health condition. This contributes to the
50 wider understanding of the challenges of 'in the wild' studies which need to be sensitive to private
51 spaces, changing personal circumstances and complicated models of consent [36, 37]
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54 Drawing upon informal networks and social support has been previously explored with patients
55 undergoing knee replacement.[38] Although participants valued their independence, most accepted
56 the need to rely on family friends to help them on their journey of having surgery and this included
57 helping them operate the home monitoring system.
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3 Post-surgery patients felt the system could benefit from more interaction. Providing visual feedback
4 (for example on movement) would have rendered this an interventional study, which would have
5 gone beyond the scope of the present study however adding that capability for other studies
6 remains important future development work.
7

8 **Strengths and Weakness of the study**

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10 Our use of in-depth qualitative methods provided detailed insight into the experiences and views of
11 patients who were using home health technology around the time of surgery. One-to-one interviews
12 enabled us to explore and probe their views in some depth and our use of thematic analysis allowed
13 us to deepen understanding the factors that underpinned its acceptability. Although our sample was
14 relatively small, there was good age and gender diversity and some diversity in hip and knee
15 replacement. Also although the study only included people willing to have technology installed in
16 their homes we have confidence that we achieved sampling adequacy.[39] We found that no new
17 themes emerged after the 10th participant, indicating that we had achieved data saturation and were
18 able to interview a diverse cross section of participants in terms of age, gender and surgery type. A
19 potential weakness of the study is under-representation of participants across a wide range of socio-
20 economic groups. We noted for instance, that the sample only included individuals who self-
21 identified as white. The sample is reflective of national figures of the proportion of joint
22 replacements amongst different ethnic groups in England.[40] Further research could include more
23 diversity to ensure that the work is more generalisable to a range of populations and those who may
24 have had a longer length of stay in hospital or complications. It is also likely that views about the
25 SPHERE technology could have been different amongst a larger group of participants undergoing
26 TKR. The recovery profiles of patients undergoing THR and TKR differ and therefore these patients
27 may have differing capacity to benefit from technology that helps to monitor recovery and provide
28 early warning of problems that might benefit from assessment or intervention.[41]
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34 **Conclusions**

35 Patients who agreed to the technology found living with it acceptable, but we cannot conclude from
36 this sample whether all people having THR and TKR would be willing now or in the future to have the
37 system in their homes. Ultimately that willingness could be shaped by the perceived benefit of the
38 intervention or service that the technology was enabling, which is beyond the scope of this
39 preliminary study.
40

41 Participants were able to conduct their preparation for surgery and recovery afterwards, but
42 sometimes forgot to wear the wristband and to keep sensor batteries charged. Informal support
43 networks were key to enabling them to operate the smart home technology before and after
44 surgery. We recommend that development of smart home technology for use at the time of major
45 healthcare intervention consider the roles of other members of a patient's social networks in the
46 successful use of the system.
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49 Finally, for healthcare professionals and patients working together in consultation, continuous home
50 monitoring may provide a useful picture of activity and function during preparation for and recovery
51 from hip or knee replacement. The SPHERE system is currently in a development stage. Further
52 research will identify how the system will support the delivery of future services such as assisted
53 living or rehabilitation.
54

55 Contributors RGH, IC and SG conceived the idea of a qualitative exploration. All authors contributed
56 to the study design and participated in the analysis and writing. SG led on the writing and gathered
57 the data. All authors MW, AB, IC, RGH and SG commented on and approved the final version of the
58 manuscript.
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Competing Interests None declared

Patient Consent Obtained

Ethics Approval Ethical approval was received from South West – Central Bristol Research Ethics Committee (17/SW/0121) on 22 June 2017.

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Data Sharing Statement: Anonymised data may be shared via the University of Bristol Research Data Repository. Access to the data will be restricted to ensure that data is only made available to bona fide researchers for ethically approved research projects, on the understanding that confidentiality will be maintained and after a Data Access Agreement has been signed by an institutional signatory.

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3 Tables and Figures
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5 Table 1 – Participant Demographics
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7 Figure 1 – Flow chart of patient through the HEmiSPHERE study
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10 Figure 2 – Participant Recruitment
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12 Supplementary File 1 – Decision Coding Tree
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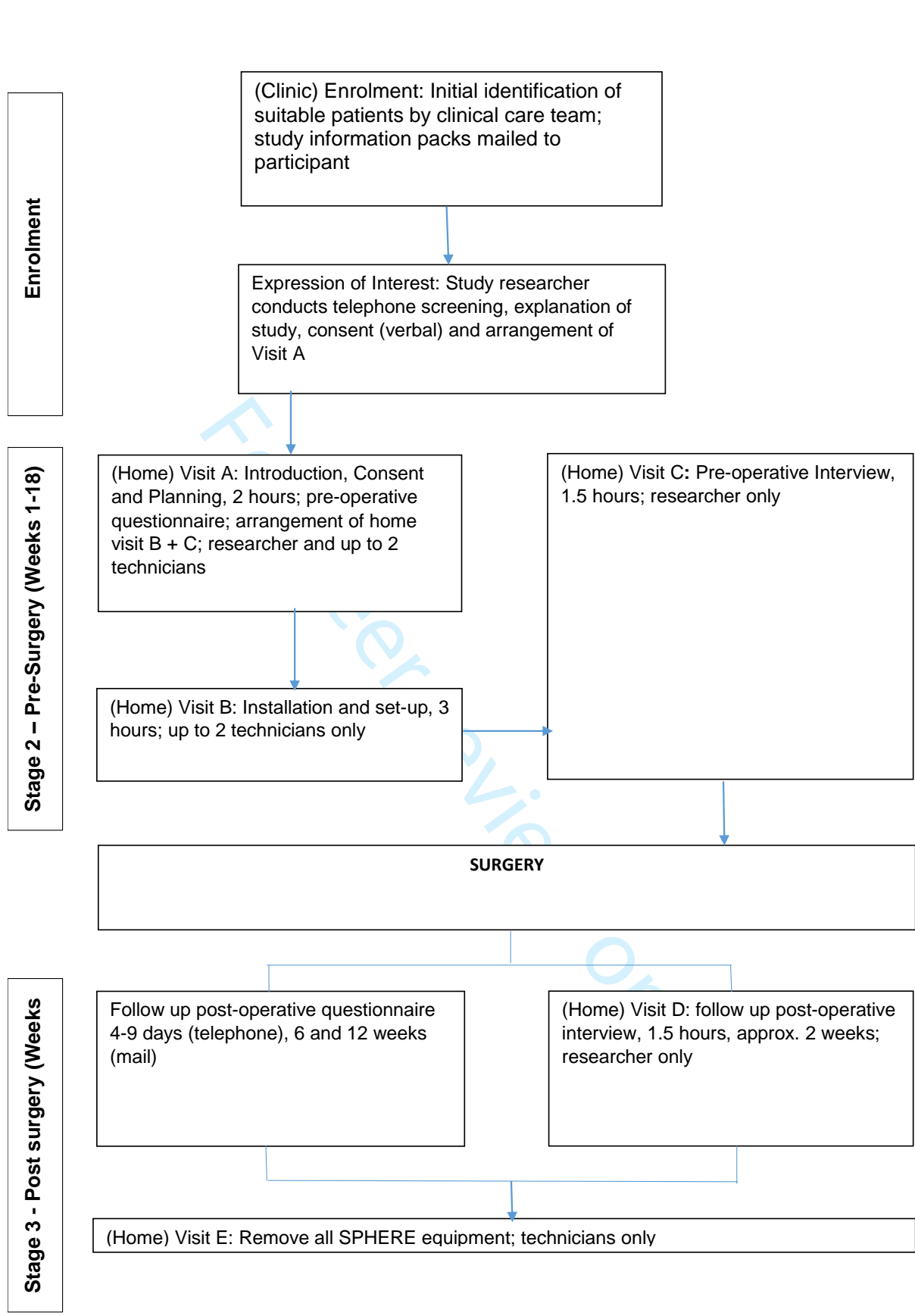
Table 1 – Participant Demographics

Pseudonym	Age at first interview (years)	Gender	Total Hip / Total Knee Replacement (THR/TKR)	Co-habitation status
Mr Hayes	70	Male	THR	Lives with spouse
Mrs Henry	67	Female	THR	Lives with spouse
Mr Price	85	Male	THR	Lives with spouse
Mrs Evans	85	Female	THR	Lives alone
Mr Connell	67	Male	TKR	Lives with spouse
Mrs Griffiths	63	Female	THR	Lives with son and daughter in law*
Mrs Wilson	89	Female	TKR	Lives alone
Mrs Murray	71	Female	THR	Lives alone
Mrs Bailey	73	Female	THR	Lives with partner
Mrs Harrison	65	Female	THR	Lives with spouse and son*
Mrs Thompson	75	Female	THR	Lives with spouse
Mr Baker	71	Male	TKR	Lives with spouse

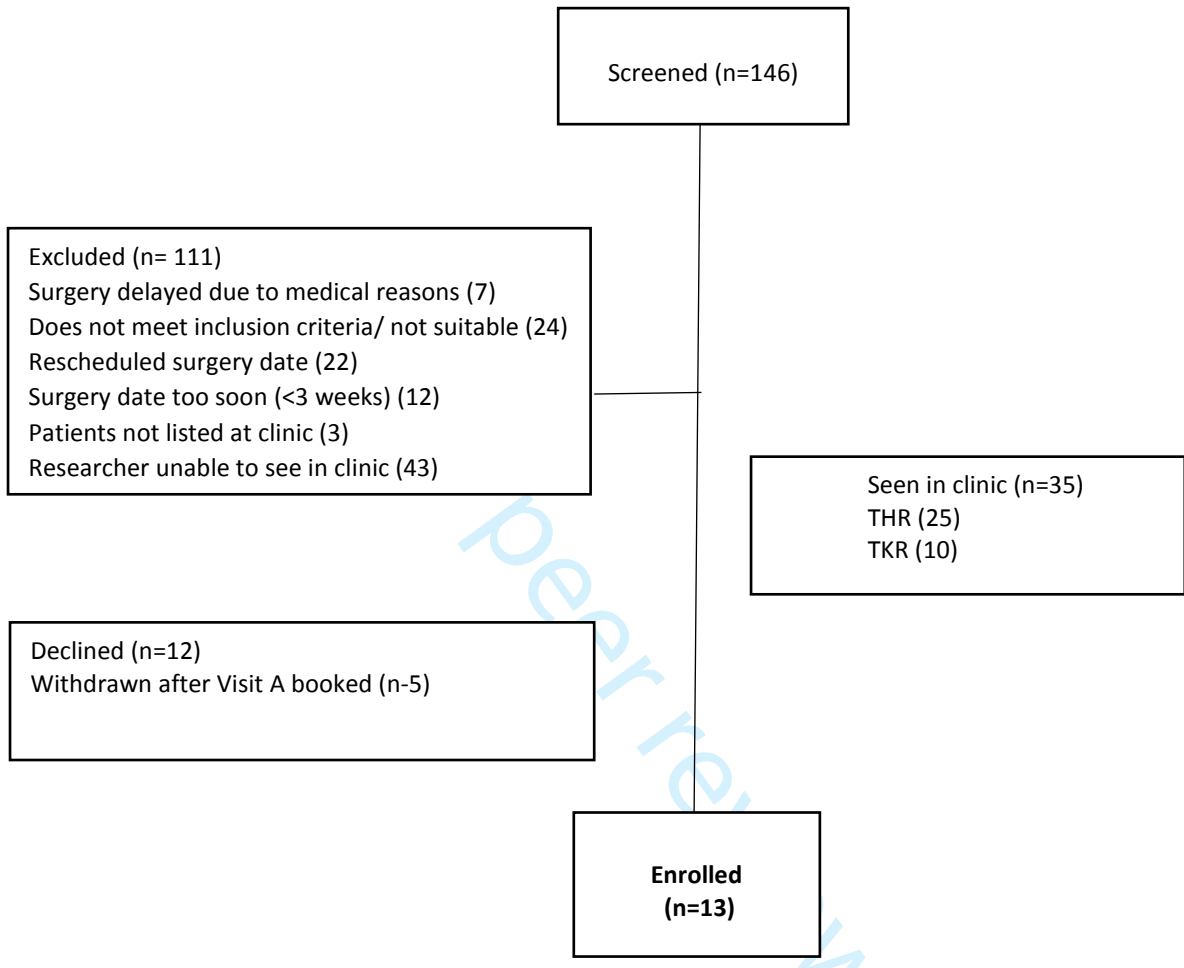
*adult household member

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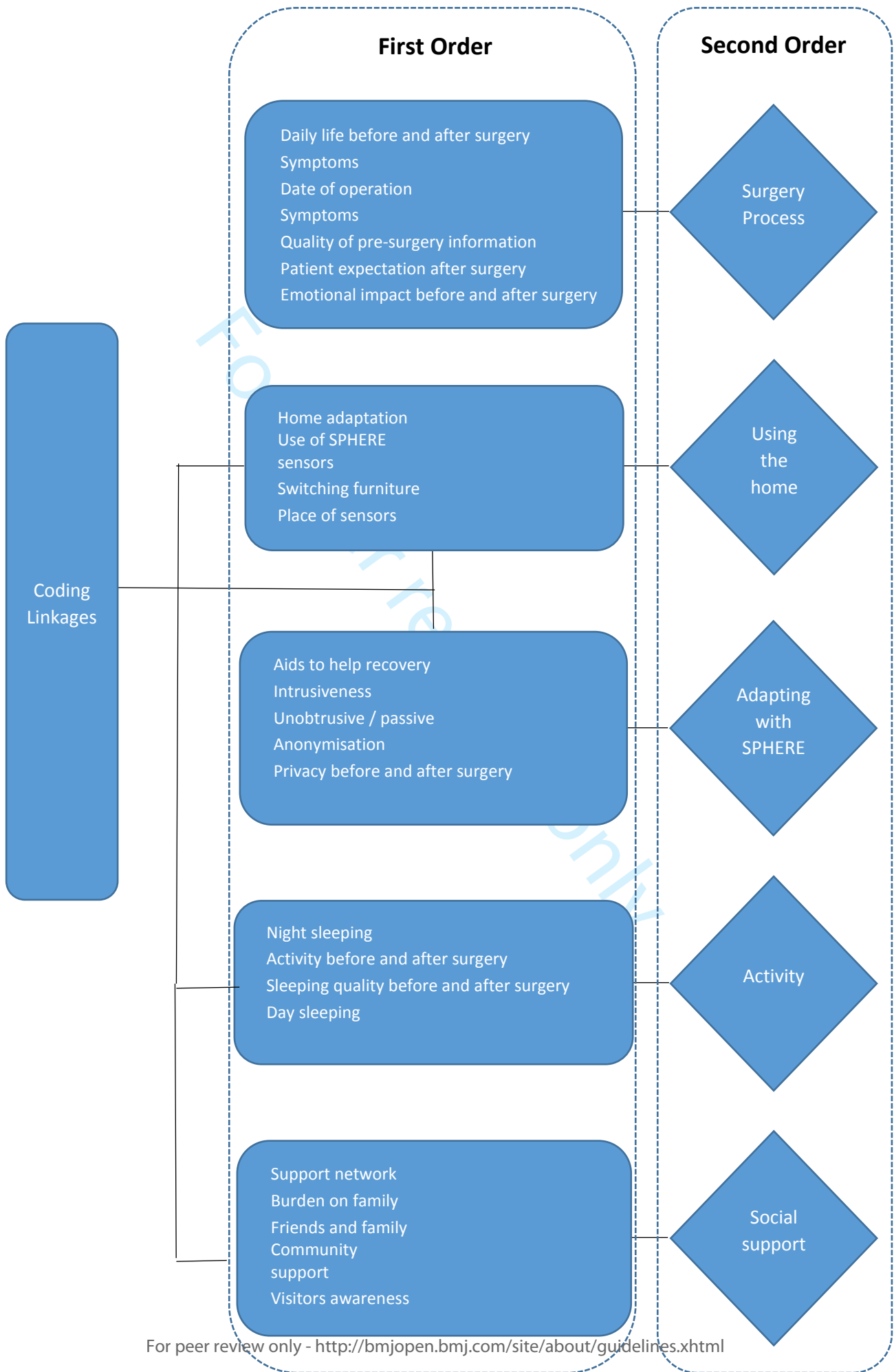
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Supplementary File 1 – Decision Coding Tree



	COREC Checklist	Page Number	Text and Comments
1			
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3		1	4 Interviews were conducted by an experienced qualitative researcher (SG) with all
4			patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint
5			2, T2) surgery.
6		2	4 Interviews were conducted by an experienced qualitative researcher (SG)
7		3	4 Interviews were conducted by an experienced qualitative researcher (SG)
8		4	4 Interviews were conducted by an experienced qualitative researcher (SG)
9		5	4 Interviews were conducted by an experienced qualitative researcher (SG) with all
10			patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint
11			2, T2) surgery.
12		6	5 All participants provided written consent before taking part during the initial planning
13			home visit.
14		7	5 Participants and interviewer were not known to each other prior to study
15			commencement; Participants and interviewer were not known to each other prior to
16			study commencement.
17		8	4,5 Background of the interviewer was not disclosed to participants;
18		9	5 Background of the interviewer was not disclosed to participants;
19		10	4,5 13 people undergoing a total hip or knee replacement for osteoarthritis were
20			consecutively sampled and enrolled onto the study.
21		11	4
22			Recruitment took place initially by postal methods, mailed an information pack
23			(invitation letter, information booklet detailing purposes of the study, description
24			including images of the sensor system, installation procedures and detailed information
25			about how their data would be used and stored and reply slip). Participants returning the
26			reply slip were contacted by the study researcher (SG) and invited to the study. Patients
27			were also screened for eligibility at their pre-operative consultation by their treating
28			consultant and then approached in clinic by a researcher to explain the study, provide an
29			information booklet and invited to study.
30		12	5, Figure 2 13 people undergoing a total hip or knee replacement for osteoarthritis were
31			consecutively sampled and enrolled onto the study.
32		13	5, Figure 2 Of the 35 patients seen in clinic, 12 declined to participate (concerns of living alone and
33			managing study requirements, too burdensome, family not keen) 5 withdrew after
34			booking Visit A (i.e. verbal agreement only). Of the 13 finally enrolled onto the study, 3
35			were recruited by post and one by radio advertisement. Further details of recruitment
36			are reported in Figure 2.
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- 14 4 All data collection took place within the home; Each interview took place in the participant's home.
- 15 5 On occasion, a household member was present.
- 16 4, Table 1 13 people undergoing a total hip or knee replacement for osteoarthritis were consecutively sampled and enrolled onto the study. Participants were aged between 63 and 89 years and comprised 5 men and 8 women, with 10 undergoing hip replacement and 3 undergoing knee replacement. Demographic information about the 13 participants is displayed in Table 1. All names are pseudonyms.
- 17 1 supplements 2-5 All participants' names were replaced with pseudonyms, and identifiable information was removed. Interviews lasted between 45 and 60 minutes and open-ended questions followed topic guides (Box 1).
- 18 4 Interviews were conducted by an experienced qualitative researcher (SG) with all patients before surgery (Time-Point 1, T1) and approximately two weeks after (Timepoint 2, T2) surgery.
- 19 5 Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[16] Supplementary field notes were taken after the interview.
- 20 5 Supplementary field notes were taken after the interview.
- 21 5 Interviews lasted between 45 and 60 minutes
- 22 12 We found that no new themes emerged after the 10th participant, indicating that we had achieved data saturation and were able to interview a diverse cross section of participants in terms of age, gender and surgery type
- 23 5 We did not return transcripts to participants but some of the preliminary results were discussed with the PPI group
- 24 5, 13 Codes were checked for consistency and validation by a second experienced researcher in the department, and the study team (SG, RGH, MW, AB); We would like to acknowledge Dr Abir Ghorayeb for double coding a portion of the transcripts and to all the patients participating in the study.
- 25 No We do not supply a coding tree, this can be requested to the authors
- 26 5
Using thematic analysis [17] the researcher (SG) read and re-read the data to ensure familiarity, coding inductively before sorting coded data into themes. [15]
- 27 5 Interviews were audio recorded, transcribed, anonymised and imported into the qualitative data management software QSR NVivo 11.[16]

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28 5 We did not return transcripts to participants but some of the preliminary results were discussed with the PPI group

29 6 We include illustrative quotations from participants, all names are pseudonyms and we indicate total hip replacement (THR) or total knee replacement (TKR) and timepoint (T1 or T2) next to each quotation.

30 11 to 13 Yes

31 6 to 11 Yes

32 6 to 11 Only the three overarching themes are reported

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