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Population-level impact of diabetes integrated care on payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Keywords:	intergrated care, Diabetes, Intervention studies, Area under the curve

Title Page

Title: Population-level impact of diabetes integrated care on payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Tables: 2

Figures: 1

References: 24

Online Appendix: 1

Keywords: Diabetes; Integrated care; Intervention studies; Area under the curve

Abstract

Objectives

Few studies have estimated the impact of diabetes integrated care at a population level. We have assessed the impact of introducing a community service led diabetes integrated care programme on inpatient payments (tariff) in rural England.

Methods

The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced community diabetes service, increasing specialist nursing, dietetic, podiatry and medical support to primary care and patients, while linking into other diabetes specialist services. Tariff data was provided by the local authority. The area between the two overlapping distribution curves of inpatient cost at baseline and follow-up (at 3 years) was used to estimate the impact of integrated care on inpatient payments on a population level.

Results

Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of patients with diabetes aged more than 70 years in the Intervention area. However, reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two adjacent areas.

Conclusion

This enhanced community diabetes services was not associated with substantially reduced inpatient payments. Alternative diabetes integrated care approaches (eg with direct primary and secondary care collaboration rather than with a community service) should be tested.

Strengths and limitations of this study

- This study raised a revised novel method to calculate the impact of interventions at population-level by comparing the distribution curves before and after the intervention.
- The 'health gain' in the revised method was clearly defined with formulated algorithm of evaluation, which broadened the utilization scenarios especially when the negative values was raised.
- With application of this novel method, this study found that the integrated diabetes care was not associated with substantially reduced inpatient payments.
- The data used in this study depended on the completeness of the coding of diabetes, although there being no systematic change in coding over this time period.

Introduction

As the social and economic impact of diabetes grows, so does the variety of attempts to improve care quality and reduce health care costs among those affected [1, 2, 3]. One approach, able to provide at least equivalent care to routine medical care with some types of patients, has been the introduction of nurses working within protocols, within medical services [4]. Other models known as 'intermediate care', including general practitioners with a special interest [5], and community diabetes nursing services [5] have been implemented, but without robust evaluation. As a proposed system, integrated care articulates all health workers and health systems around the needs of each patient and should be associated with improved outcomes and less cost [6].

However, the impact of a population based integrated care intervention is difficult to measure on an individual level. One randomised trial of an intermediate care service showed no impact on outcomes at greater cost [7]. By their nature, randomised controlled trials are difficult to utilising for assessing the impact of a complete system change at a population level, even using a cluster approach. Sarkadi et al have proposed a method to look at population outcomes in their own right in the quest of understanding how interventions work at a population level [8]. We now use this approach to assess changes in population based inpatient payment data before and during an integrated care intervention, viewing the level and distribution of inpatient payments in the population as the unit of interest.

Methods

East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population 7,790) is largely rural, with a small number of socioeconomically deprived communities. There is no major hospital, falling within 4 major hospital catchment areas. Some diabetes outcomes have been historically poor [9]. A separate, local, diabetes specialist nurse (DSN) led community service was introduced in 2003 [10]. From April 2009, this

was replaced with a new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in an attempt to address continuing health disparities [11]. The components of the DICI has been described in the previous publications [12]. The health district includes two other areas, Huntingdonshire and Greater Cambridge, which did not receive the full intermediate team and are able to serve as 'control' areas. .

De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI contract commenced) and March 2012. Practice, patient age, elective/non elective status, ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes was considered present if E10-E14 was in any ICD10 field and, as the primary cause of admission if coded in the first field [13, 14]. Inpatient payments recorded in 2008-2009 were used as baseline, to compare with that recorded in 2011-2012 as the end of the intervention period. Using the Sarkadi et. al. method, the mean and standard deviation for normal distributions before and after the intervention can be estimated. The "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental **Error! Reference source not found.** left). In our study, the 'health gain' represents the proportion of patients with reduced inpatient payments between the baseline and intervention period. However when using real data to estimate parameters for two normal distributions, it is unlikely that the two curves have the same standard deviation. In our case, the two curves will have crossover points. To overcome this, we have modified the Sarkadi's method as described in supplemental technical appendix 1.

Bootstrapping is used to obtain a p value for the probability of health gain larger than zero. We randomly sampled data points with replacements from the original data separately for the baseline and follow-up, so that we obtain bootstrapped data with the

same numbers of data points. These are used to obtain an estimation of the health gain after perturbation. This process is repeated 1000 times. The probability of observing estimations less than or equal to zero is calculated, and used as the approximation of the p value for testing whether health gain is significantly larger than zero.

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

All analyses were conducted in R [Version 3.1]. Ethics approval was received from the National Research Ethics Service Committee- East of England.

Results

The inpatient payments during the baseline period and the intervention period are shown in Table 1 by area and age group. In each area and age group, a lower individual median inpatient payment was more likely to be found in the intervention period.

Figure-2 shows the distribution of the inpatient payments in people with type 2 diabetes in the baseline and intervention periods. This illustrates the effect of the integrated care intervention, as the left-moving curve in the intervention period indicates the potential inpatient payment saving at a population level. The magnitude of the intervention at the population level iss presented in Table-2. In the intervention area, East Cambridge and Fenland, 2.74% (95 Confidence Interval (CI) 1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment, compared with the population in the baseline period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in

3.20 (1.77 to 7.20) % of patients aged less than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively. Significant 'health gain' was not identified within the population in Huntingdonshire over the study period. The health gain distributions are presented in supplemental Figure-2 to illustrate the health gains at a population level.

Discussion

We have used a novel way, calculating the total health gain (proportion of people with reduced inpatient payments) assuming a Gaussian distribution, to assess the results of integrated care in the diabetic population of areas in Cambridgeshire through a population lens. The study revealed a possible limited effect of the new integrated care approach on inpatient payments, as 2.7% of patients aged more than 70 years had reduced inpatient payments in the intervention area, East Cambridge and Fenland. However, reductions were also seen in one of the control areas, Greater Cambridge, where inpatient payments were not only reduced in those age over 70 years (4.1%), but also among those aged less than 70 years (3.2%). However, the 95% confidence intervals overlapped across the 3 areas, so we have not shown any differences between the areas.

Significant improvements in diabetes care can occur with multifaceted interventions [15] including disease management in the US [16] and integrated care in Germany [17] and these can be associated with reductions in hospital costs [18]. The integrated care intervention was successfully implemented across the area, with positive patient experience, improved practice nurse clinical confidence, and early reports of clinical benefit [11, 12, 19]. It is therefore surprising that although some (small) positive benefit was observed in the intervention area, the return on the investment of GBP250,000 was not greater and possibly less than in one of the control areas. Elsewhere, diabetes

integrated care interventions have generally been more effective within single providers or in contexts where multiple primary care organisations work with a single specialist provider under an integrated insurance scheme [5]. The integrated care intervention carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie payments) to hospital outpatients. This philosophy, rather than progressing to truly integrated services carried through the intervention period. It was perhaps to be expected that attempts at creating greater integration in information management, clinical governance, budget and overall management were agreed but not implemented, actions more achievable within a single organization. There was an attempt to create a single equal partner network model [20] nearing the end of the intervention period, but this as not funded by the local commissioners.

The failure to implement integrated information management, almost certainly contributed to communication and integration difficulties. Most integrated care initiatives attempt to include data sharing [21] and this was not possible within the local information governance arrangements. This was noticed by the patients and was a source of frustration. Interestingly, integration was perceived as happening when there was one person 'fronting up' for all those involved. Case management has been proposed as one approach to integration, and requires the case manager to corral and coordinate the services for a given individual [16].

Whether our findings are due to a unique set of circumstances, or expected as part of a 3 compartment model (primary care, intermediate care, and secondary care) is unclear, but there are indications that the circumstances are not special. There are calls for more integration and less fragmentation in health care [21], yet the evidence on what works in England is limited [22, 23]. The latest changes in commissioning in the English NHS, with emphasis on the need to consider 'Any qualified Provider' in service delivery, and

associated market procurement approaches, could well impair the quality of diabetes care while increasing overall cost, if the experience here is reproduced elsewhere.

Similarly, as a 'natural experiment', it was not possible to measure the impact of integrated care on inpatient payments at an individual level. Instead, we estimated the proportion of the population showing 'heath gain' (reduced inpatient payments) from the integrated care intervention by using the distribution curve of inpatient payment. Although the method was within the conceptual framework proposed by Sakardi, some modifications to the methodology were made to overcome methodological drawbacks, for example requiring the same standard deviation for two Gaussian curves: something unlikely to occur in real scenarios. We believe this revised method would be more applicable to evaluate the 'health gain' for interventions at a population level.

There are limitations to our study. This was not a randomised trials, so any changes could be due to secular trends, although we do compare with the two other areas in Cambridgeshire. The data depended on the completeness of the coding of diabetes, and there being no systematic change in coding over this time period. We found that at least one provider had high diabetes ascertainment [24].

In conclusion, we have applied a modified novel strategy to measure 'health gain' associated with an integrated care intervention at a population level. We found that there were no differences in inpatient payments. Our findings suggest that irrespective of the ideal principles behind integration, linking multiple health providers to deliver population based diabetes care is complex and improvements in health outcomes remain difficult to achieve.

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Contributors

D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods and revised the manuscript; Y.C. validated the method and re-analysed the data independently; Z.Z. designed the analysis framework and revised manuscript; D.S. designed the study, revised the analysis framework, revised the manuscript and interpreted the findings.

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Competing interests

None declared.

Ethics approval

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient cost in people with type 2 diabetes and possible effects of an integrated care on the curve.

The differences between the respective areas under the curve are shaded. Health gains for participants with lower inpatient cost.
Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.

Table 1. Distribution of age and inpatient cost among people with type 2 diabetes by region and year

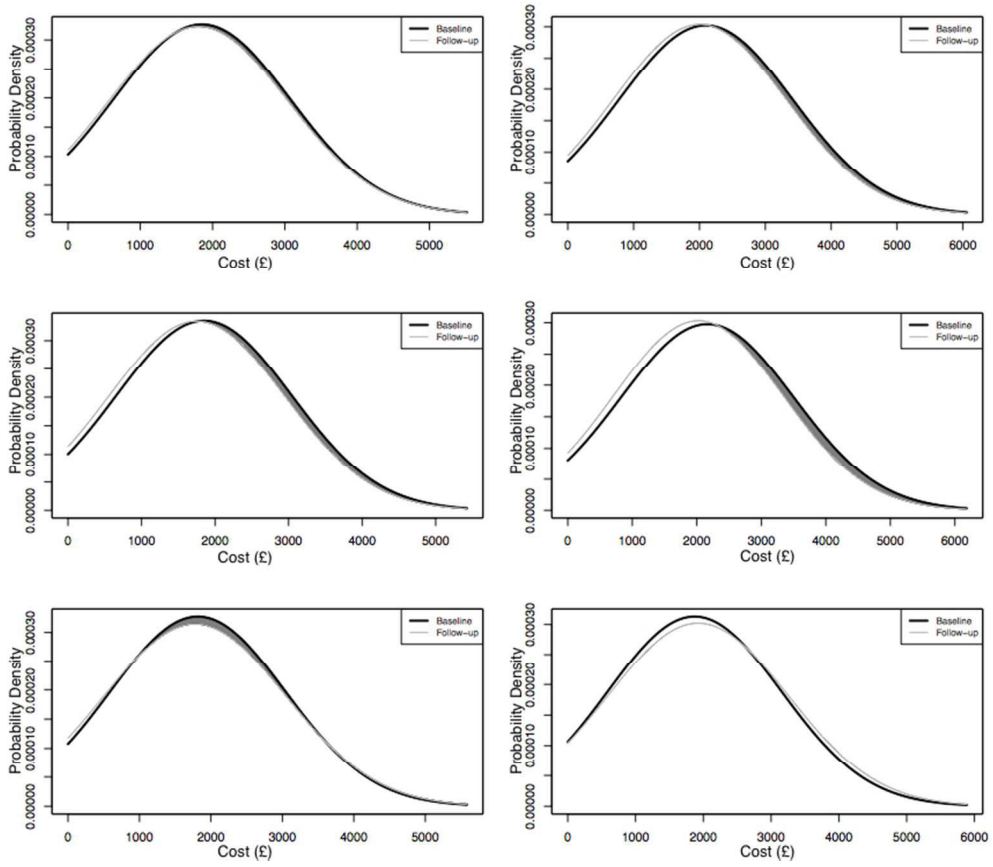
		East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
		<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	Age,year	60 (51, 65)	78 (74, 82)	61 (52, 65)	77 (73, 83)	58 (48, 64)	78 (74, 82)
	Cost, £	819 (506, 1860)	911 (531, 2473)	808 (504, 1707)	808 (531, 2251)	933 (597, 1997)	1151 (611, 2638)
2011-2012	Age,year	60 (51, 65)	78 (74, 83)	60 (48, 66)	77 (73, 83)	59 (50, 66)	79 (75, 84)
	Cost, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

The median (inter-quartile rage (IQR)) was presented both for age and cost.

Table 2. The estimated absolute 'health cost gain (impact)' after the intervention by age and region

		Impact	95% confidence interval	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	0.015802	(-0.01905, 0.04878)	0.051948
	≥70 years	0.027425	(0.012896 ,0.058123)	0.014985
Huntingdonshire	< 70 years	0.018321	(-0.02444, 0.058739)	0.220779
	≥70 years	-0.02064	(-0.05535, 0.037903)	0.737263
Greater Cambridge	< 70 years	0.03201	(0.01774, 0.072033)	0.004995
	≥70 years	0.041415	(0.022678, 0.078574)	0.000999

The health cost gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced heath cost after the integrated care at population level.



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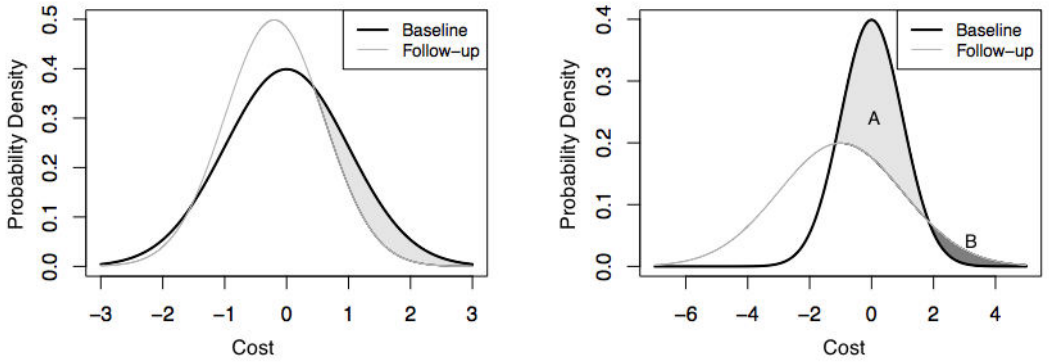
Online supplemental 1: Technical Appendix

Estimating intervention impact, and confidence interval estimation

Sarkadi et. al. described a method to assess the population-level impact of interventions using normal distributions to approximate the actual data. After estimating the mean and standard deviation for the normal distributions before and after intervention, the "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental Figure 1 below).

Supplemental Figure 1. Normal distribution curves.



To estimate the confidence interval, Sarkadi et. al. proposed to start from estimating the confidence intervals of mean and standard deviation for the two normal distributions. The point estimation of the mean for the baseline is μ_1, and the lower and higher bounds of the confidence interval at a certain level (for example, 95% confidence interval) are μ_{1min} and μ_{1max}, respectively; the estimation of standard deviation at baseline is σ_1, and the two bounds of confidence interval are σ_{1min} and σ_{1max}. Similarly, for the follow-up data, point estimations are μ_2 and σ_2, and the confidence bounds for them as μ_{2min}, μ_{2max}, and σ_{2min}, σ_{2max}. Denote the health gain as a function of the parameters for the two normal distributions as F (μ_1, σ_1,,μ_2,σ_2). Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as MIN(F (μ_{1min}, σ_{1max},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2min},σ_{2max})), and MAX(F (μ_{1max}, σ_{1min},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2max},σ_{2min})).

Modification of the impact estimation

There are a few situations where the original estimation algorithm is ambiguous.

When using real data to estimate parameters for the two normal distributions, it is unlikely that the two curves have the same standard deviation. In this case, the two curves will have to crossover points.

(1) If the two distributions are shown as in the left graph in Supplemental Figure 1, where the density of the follow-up is always lower compared to the baseline when observed data is larger than the larger of the two crossover points, it is easy to get the health gain estimation as the shaded area.

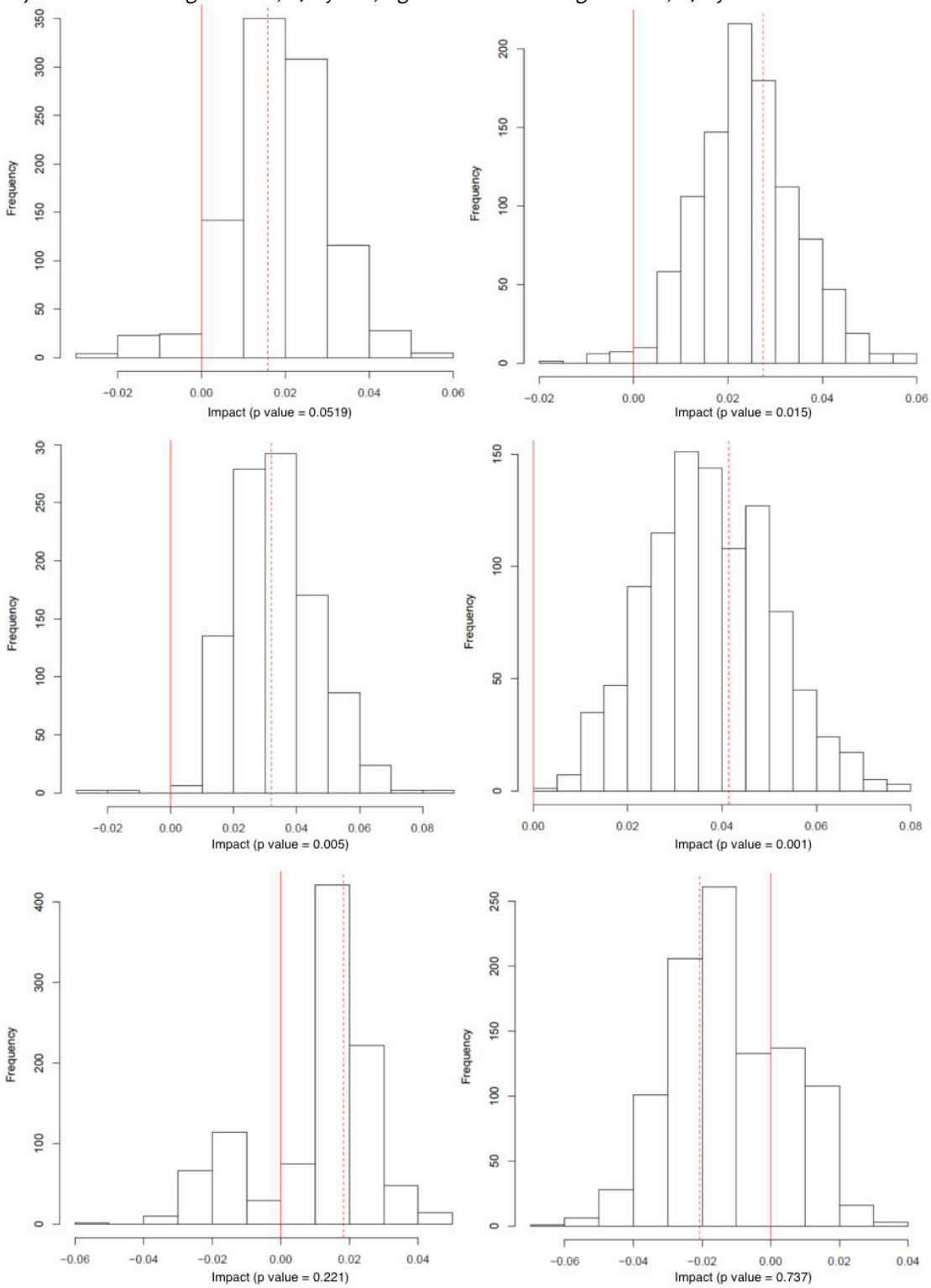
(2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear definition of the health gain. Here, we will define it as the difference of the two shaded areas A and B.

(3) The original method only discussed the case where the estimated mean after intervention is no larger than that of the baseline. We need to define health gain estimation even though this is not true, so that we can have negative estimations when calculating confidence intervals. If the estimated mean after intervention increases, we switch the places of the two curves to estimate a positive health gain as previously, and then put a negative sign to this value and take it as the negative health gain.

Online supplemental 2: Figure 2. The health cost gain (impact) distribution

The health cost gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced heath cost after the 3 year integrated care at population level.

Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.



STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract Response: Yes, it has been indicated on page 2.
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found Response: Yes, it has been indicated on page 2.
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported Response: Yes, it has been described in the 'Introduction' section on page 4.
Objectives	3	State specific objectives, including any prespecified hypotheses Response: Yes, it was indicated in the last paragraph of the Introduction section on page 4.
Methods		
Study design	4	Present key elements of study design early in the paper Response: It was described in the method section on page 4.
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection Response: It was described in the method section on page 4-5.
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up Response: It was described in the method section on page 5.
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed Response: Not applicable
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable Response: It was described in the method section on page 5.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group Response: It was described in the method section on page 5.
Bias	9	Describe any efforts to address potential sources of bias Response: It was described in the method section on page 5.
Study size	10	Explain how the study size was arrived at Response: There was no sample in this study. Any inpatient income of each patient in the intervention area and control was recorded by CCG as described on page 5.
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why Response: It was described in the method section on page 5.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding Response: It was described both in the method section on page 5 and in the online supplemental.
		(*b*) Describe any methods used to examine subgroups and interactions Response: It was described in the method section on page 5 and in the online

	supplemental.
	(*c*) Explain how missing data were addressed Response: Not applicable. Any inpatient income of each patient in the intervention area and control was recorded by CCG as described on page 5.
	(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed Response: It was described in the method section as defined as the financial year of the CCG audit team on page 5.
	(*e*) Describe any sensitivity analyses Response: the analysis were repeated in the age-stratification and verified by bootstrapping on page 5 and 6.

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed Response: As the evaluation at population level, there was no information at individual level was used in this study as described on page 6.
		(b) Give reasons for non-participation at each stage Response: Not applicable.
		(c) Consider use of a flow diagram Response: Not applicable.
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders Response: As the evaluation on the population level, the individual information was not utilised in this study as described on page 6. But the outcome on population level by regions and time periods was described in table-1 on page 13.
		(b) Indicate number of participants with missing data for each variable of interest Response: Not applicable.
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount) Response: It was described in the method section as defined as the financial year of the CCG audit team on page 5 and same follow up time defined by the financial year was equal across populations.
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time Response: It was described in table-1 on page 13.
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included Response: The health gain was described in table-2 with confidence interval tested by bootstrapping on page 13.
		(*b*) Report category boundaries when continuous variables were categorized Response: Not applicable.
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period Response: Not applicable.
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses Response: Not applicable.
Discussion		
Key results	18	Summarise key results with reference to study objectives Response: It was described in the page-8.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias Response: It was described in the page-9.
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence Response: It was described in the page-9.

Generalisability	21	Discuss the generalisability (external validity) of the study results Response: It was described in the page-9.
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

Response: It was described in the page-11.

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

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

BMJ Open

Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Keywords:	intergrated care, Diabetes, Intervention studies, Area under the curve

Title Page

Title: Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Figures: 1

References: 26

Online Appendix: 1

Keywords: Diabetes; Integrated care; Intervention studies; Area under the curve

Abstract

Objectives

Few studies have estimated the effect of diabetes integrated care at a population level. We have assessed the impact of introducing a community service led diabetes integrated care programme on commissioner payments (tariff) for inpatient care in rural England.

Methods

The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced community diabetes service, increasing specialist nursing, dietetic, podiatry and medical support to primary care and patients, while linking into other diabetes specialist services. Commissioner data was provided by the local authority. The difference in area between the two overlapping distribution curves of inpatient payments at baseline and follow-up (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient payments on a population level.

Results

Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of patients with diabetes aged more than 70 years in the Intervention area. However, reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two adjacent areas.

Conclusion

This enhanced community diabetes services was not associated with substantially reduced inpatient payments. Alternative diabetes integrated care approaches (eg with direct primary and secondary care collaboration rather than with a community service) should be tested.

Strengths and limitations of this study

- This study raised a revised novel method to calculate the impact of interventions at population-level by comparing the area under the distribution curves before and after the intervention.
- The 'health gain' in the revised method was clearly defined with a formulated algorithm of evaluation, which broadened the utilization scenarios especially when negative values were raised.
- With application of this novel method, this study found that the integrated diabetes care was not associated with substantially reduced inpatient payments.
- The data used in this study depended upon the completeness of the coding for diabetes in the GP records. The impact of this potential ascertainment bias should have been steady as no systematic change in coding should have occurred over this time period.

Introduction

As the social and economic impact of diabetes grows, so does the variety of attempts to improve care quality and reduce health care costs among those affected [1, 2, 3, 4]. One approach, able to provide at least equivalent care to routine medical care with some types of patients, has been the introduction of nurses working within protocols, within medical services [5]. Other models known as 'intermediate care', including general practitioners with a special interest [6], and community diabetes nursing services [6] have been implemented, but without robust evaluation. As a proposed system, integrated care articulates all health workers and health systems around the needs of each patient and should be associated with improved outcomes and less cost [7].

However, the impact of a population based integrated care intervention is difficult to measure on an individual level. One randomised trial of an intermediate care service achieved minimal actual incremental benefit [8]. By their nature, randomised controlled trials are difficult to utilise when assessing the impact of a complete system change at a population level. . Sarkadi et al have proposed a method to look at population outcomes in their own right in the quest of understanding how interventions work at a population level [9]. Under the English National Health Service (NHS), public inpatient care is paid for from taxation through local commissioners. These payments do not generally cover the hospital costs of inpatients with diabetes [10], but can provide an NHS commissioner perspective that reflects both acuity and complexity, beyond eg length of stay. We have now used the Sarkadi approach to assess whether any changes in population based commissioner inpatient payment data occurred during a diabetes integrated care intervention by viewing the level and distribution of commissioner inpatient payments in the population as the unit of interest.

Methods

East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population 7,790) is largely rural, with a small number of socioeconomically deprived communities [6]. There is no local major hospital (with eg an emergency department), falling within the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led community service was introduced in 2003 [12]. From April 2009, this was replaced with a new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in an attempt to address continuing health disparities [13]. The components of the DICI has been described in the previous publications [14]. The health district includes two other areas, Huntingdonshire and Greater Cambridge, which did not receive the full intermediate team and are able to serve as 'control' areas, although each hospital based service would have continued with its own internal service developments. We have previously reported no impact on metabolic control or hospitalisation rates in spite of full implementation of the service [6].

De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI contract commenced) and March 2012. Practice, patient age, elective/non elective status, ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes was considered present if E10-E14 was in any ICD10 field and, as the primary cause of admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009 were used as baseline, to compare with that recorded in 2011-2012 as the end of the intervention period. Using the Sarkadi et. al. method, the mean and standard deviation for normal distributions before and after the intervention can be estimated. The "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental **Error! Reference source not found.** left). In our study, 'health gain' represents the proportion

of patients with reduced inpatient payments between the baseline and intervention period. The reduction in commissioner payments is seen as a 'health gain', as under the NHS, such liberation of public funds can be used elsewhere to achieve a gain in health.

Sarkadi's method has outlined ways to calculate the impact when the two distributions have the same standard deviation (SD), or when the follow-up group has smaller mean and smaller SD at the same time. However we have noticed when using real data that the follow-up-group might have smaller mean but larger SD. To accommodate this situation, we have modified the Sarkadi's method as described in supplemental technical appendix 1.

Bootstrapping is used to obtain a p value for the probability of health gain larger than zero. We randomly sampled data points with replacements from the original data separately for the baseline and follow-up, so that we obtain bootstrapped data with the same numbers of data points. These are used to obtain an estimation of the health gain after perturbation. This process is repeated 1000 times. The probability of observing estimations less than or equal to zero is calculated, and used as the approximation of the p value for testing whether health gain is significantly larger than zero.

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. Age data were provided allowing analyses to be undertaken above and below the median age (70 years) to assess any related variation. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

All analyses were conducted in R [Version 3.1]. Ethics approval was received from the National Research Ethics Service Committee- East of England.

Results

The sample size of inpatient payment records during the baseline and the intervention period in each region is presented in Table 1. The inpatient payments during the baseline period and the intervention period are shown in Table 2 by area and age group. In each area and age group, a lower individual median inpatient payment was more likely to be found in the intervention period.

Figure-1 shows the distribution of the inpatient payments in people with type 2 diabetes in the baseline and intervention periods. This illustrates the effect of the integrated care intervention, as the left-moving curve in the intervention period indicates the potential inpatient payment saving at a population level. The magnitude of the intervention at the population level is presented in Table-3. In the intervention area, East Cambridge and Fenland, 2.74% (95 Confidence Interval (CI) 1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment, compared with the population in the baseline period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in 3.20 (1.77 to 7.20) % of patients aged less than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively. Significant 'health gain' was not identified within the population in Huntingdonshire over the study period. The health gain distributions are presented in supplemental Figure-2 to illustrate the health gains at a population level.

The gamma-distribution and log-normal distribution was attempted to be applied in the study which did not significantly make improvement in fitting the data distributions. The

G-computation [17] was also applied in the data and restricted by the data access, no significant changes was observed.

Discussion

We have used a novel way, calculating the total health gain (proportion of people with reduced inpatient payments) assuming a Gaussian distribution, to assess the results of integrated care in the diabetic population of areas in Cambridgeshire through a population lens. The study revealed a possible limited effect of the new integrated care approach on inpatient payments, as 2.7% of patients aged more than 70 years had reduced inpatient payments in the intervention area, East Cambridge and Fenland. However, reductions were also seen in one of the control areas, Greater Cambridge, where inpatient payments were not only reduced in those age over 70 years (4.1%), but also among those aged less than 70 years (3.2%). However, the 95% confidence intervals overlapped across the 3 areas, so we have not shown any differences between the areas.

Significant improvements in diabetes care can occur with multifaceted interventions [18] including disease management in the US [19] and integrated care in Germany [20] and these can be associated with reductions in hospital costs [21]. The integrated care intervention was successfully implemented across the area, with positive patient experience, improved practice nurse clinical confidence, and early reports of clinical benefit [13, 14, 22]. It is therefore surprising that although some (small) positive benefit was observed in the intervention area, the return on the investment of GBP250,000 was not greater and possibly less than in one of the control areas. Elsewhere, diabetes integrated care interventions have generally been more effective within single providers

or in contexts where multiple primary care organisations work with a single specialist provider under an integrated insurance scheme [6]. The integrated care intervention carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie payments) to hospital outpatients. This philosophy, rather than progressing to truly integrated services carried through the intervention period, albeit as part of a wider programme that included 'vertical integration' developments. It was perhaps to be expected that attempts at creating such greater 'vertical' integration in information management, clinical governance, budget and overall management were agreed but not implemented, actions more achievable within a single organization. There was an attempt to create a single equal partner network model [23] nearing the end of the intervention period, but this as not funded by the local commissioners.

The failure to implement integrated information management, almost certainly contributed to communication and integration difficulties. Most integrated care initiatives attempt to include data sharing [24] and this was not possible within the local information governance arrangements. This was noticed by the patients and was a source of frustration. Interestingly, integration was perceived as happening when there was one person 'fronting up' for all those involved. Case management has been proposed as one approach to integration, and requires the case manager to corral and coordinate the services for a given individual [19].

Whether our findings are due to a unique set of circumstances, or expected as part of a 3 compartment model (primary care, intermediate care, and secondary care) is unclear, but there are indications that the circumstances are not special. There are calls for more integration and less fragmentation in health care [24], yet the evidence on what works in England is limited [25, 26]. The latest changes in commissioning in the English NHS, with emphasis on the need to consider 'Any qualified Provider' in service delivery, and

associated market procurement approaches, could well impair the quality of diabetes care while increasing overall cost, if the experience here is reproduced elsewhere.

Similarly, as a 'natural experiment', it was not possible to measure the impact of integrated care on inpatient payments at an individual level. Instead, we estimated the proportion of the population showing 'heath gain' (reduced inpatient payments) from the integrated care intervention by using the distribution curve of inpatient payment. Although the method was within the conceptual framework proposed by Sakardi, some modifications to the methodology were made to overcome methodological drawbacks, for example requiring the same standard deviation for two Gaussian curves: something unlikely to occur in real scenarios. We believe this revised method would be more applicable to evaluate the 'health gain' for interventions at a population level.

There are limitations to our study. This was not a randomised trials, so any changes could be due to secular trends, although we do compare with the two other areas in Cambridgeshire. The data depended on the completeness of the coding of diabetes, and there being no systematic change in coding over this time period. We found that at least one provider had high diabetes ascertainment [10]. Data access restrictions prevented adjustment for some important co-variables. As the data used was record- rather than individual based, repeat inpatient records were unable to be linked, however, the record-based data still provides a range of plausible estimations. Moreover, within a relatively fixed diabetes population served by a local 'closed' inpatient care and tariff system, the likelihood for patients having a second hospital admission, would still be relatively low (although higher than those without diabetes) [10]. In another words, inpatient payments at two time-points are considered completely independent of each other. We acknowledge that this current analysis still yields findings subject to confounding bias unable to be measured in this study. The 'impact' observed in our study may therefore

only reflect measured changes in the DICI and 'control' regions respectively, rather than due to the DICI itself, as the DICI care model was not randomly assigned.

In conclusion, we have applied a modified novel strategy to measure 'health gain' associated with an integrated care intervention at a population level. We found that there were no differences in inpatient payments. Our findings suggest that irrespective of the ideal principles behind integration, linking multiple health providers to deliver population based diabetes care is complex and improvements in health outcomes remain difficult to achieve.

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Contributors

D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods and revised the manuscript; Y.C. validated the method and re-analysed the data independently; Z.Z. designed the analysis framework and revised manuscript; D.S. designed the study, revised the analysis framework, revised the manuscript and interpreted the findings.

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Competing interests

None declared.

Ethics approval

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient cost in people with type 2 diabetes and possible effects of an integrated care on the curve.

The differences between the respective areas under the curve are shaded. Health gains for participants with lower inpatient cost.
Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.

Table 1: Sample size of the inpatient payment records

	East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
	<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	2012	2028	1494	1664	1575	1329
2011-2012	2431	2756	1871	1990	2004	1823

Table 2. Distribution of age and inpatient cost among people with type 2 diabetes by region and year

		East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
		<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	**Age,year**	60 (51, 65)	78 (74, 82)	61 (52, 65)	77 (73, 83)	58 (48, 64)	78 (74, 82)
	Cost, £	819 (506, 1860)	911 (531, 2473)	808 (504, 1707)	808 (531, 2251)	933 (597, 1997)	1151 (611, 2638)
2011-2012	**Age,year**	60 (51, 65)	78 (74, 83)	60 (48, 66)	77 (73, 83)	59 (50, 66)	79 (75, 84)
	Cost, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

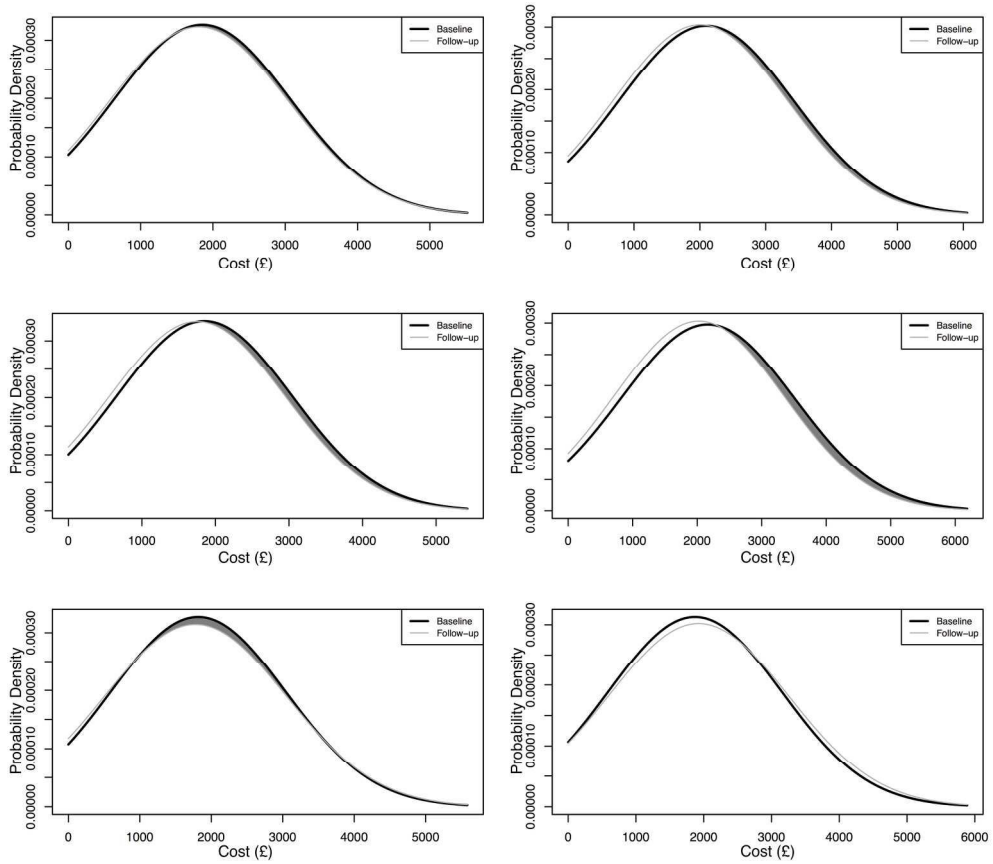
The median (inter-quartile rage (IQR)) was presented both for age and cost.

Table 3. The estimated absolute 'health cost gain (impact)' after the intervention by age and region

		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	1.58	(-1.91, 4.88)	0.051948
	≥70 years	2.74	(1.29 , 5.81)	0.014985
Huntingdonshire	< 70 years	1.83	(-2.44, 5.87)	0.220779

	≥70 years	-2.06	(-5.54, 3.79)	0.737263
Greater Cambridge	< 70 years	3.20	(1.77, 7.20)	0.004995
	≥70 years	4.14	(2.27, 7.86)	0.000999

The health cost gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced heath cost after the integrated care at population level.



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CHEERS Checklist

Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section	Item No	Recommendation	Reported on page No/line No
Title and Abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page-1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page-2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Page-4
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 4-5
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 5
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 5
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 5
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Page 5
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	Page 5
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 5-6
Measurement of effectiveness	11a	*Single study-based estimates*: Describe fully the design features of the single effectiveness study and why the single	Page 5-6

		study was a sufficient source of clinical effectiveness data.	
	11b	*Synthesis-based estimates*: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Page 6
Estimating resources and costs	13a	*Single study-based economic evaluation*: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation*: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Page 6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 6
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 6
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Page 6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 6
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 7
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If	Page 7

		applicable, report incremental cost-effectiveness ratios.	

Characterizing uncertainty	20a	*Single study-based economic evaluation*: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation*: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Page 7-8
Characterizing heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	Page 7-8
Discussion			
Study findings, limitations, generalizability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 8
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 13
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 13

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Title Page

Title: Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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Figures: 1

References: 26

Online Appendix: 1

Keywords: Diabetes; Integrated care; Intervention studies; Area under the curve

Abstract

Objectives

Few studies have estimated the effect of diabetes integrated care at a population level. We have assessed the impact of introducing a community service led diabetes integrated care programme on commissioner payments (tariff) for inpatient care in rural England.

Methods

The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced community diabetes service, increasing specialist nursing, dietetic, podiatry and medical support to primary care and patients, while linking into other diabetes specialist services. Commissioner data was provided by the local authority. The difference in area between the two overlapping distribution curves of inpatient payments at baseline and follow-up (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient payments on a population level.

Results

Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of patients with diabetes aged more than 70 years in the Intervention area. However, reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two adjacent areas.

Conclusion

This enhanced community diabetes services was not associated with substantially reduced inpatient payments. Alternative diabetes integrated care approaches (eg with direct primary and secondary care collaboration rather than with a community service) should be tested.

Strengths and limitations of this study

- This study ued a novel method to calculate the impact of interventions at a population-level by comparing the area under the distribution curves before and after an intervention.
- The 'health gain' in the revised method was clearly defined with a formulated algorithm of evaluation, which broadened the utilization scenarios especially when negative values were raised.
- With application of this novel method, this study found that the integrated diabetes care approach used was not associated with substantially reduced inpatient payments.
- The data used in this study depended upon the completeness of the coding for diabetes in the GP records. The impact of this potential ascertainment bias should have been steady as no systematic change in coding was known to have occurred over this time period.

Introduction

As the social and economic impact of diabetes grows, so does the variety of attempts to improve care quality and reduce health care costs among those affected [1, 2, 3, 4]. One approach, able to provide at least equivalent care to routine medical care with some types of patients, has been the introduction of nurses working within protocols, within medical services [5]. Other models known as 'intermediate care', including general practitioners with a special interest [6], and community diabetes nursing services [6] have been implemented, but without robust evaluation. As a proposed system, integrated care articulates all health workers and health systems around the needs of each patient and should be associated with improved outcomes and less cost [7].

However, the impact of a population based integrated care intervention is difficult to measure on an individual level. One randomised trial of an intermediate care service achieved minimal actual incremental benefit [8]. By their nature, randomised controlled trials are difficult to utilise when assessing the impact of a complete system change at a population level. . Sarkadi et al have proposed a method to look at population outcomes in their own right in the quest of understanding how interventions work at a population level [9]. Under the English National Health Service (NHS), public inpatient care is paid for from taxation through local commissioners. These payments do not generally cover the hospital costs of inpatients with diabetes [10], but can provide an NHS commissioner perspective that reflects both acuity and complexity, beyond eg length of stay. We have now used the Sarkadi approach to assess whether any changes in population based commissioner inpatient payment data occurred during a diabetes integrated care intervention by viewing the level and distribution of commissioner inpatient payments in the population as the unit of interest.

Methods

East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population 7,790) is largely rural, with a small number of socioeconomically deprived communities [6]. There is no local major hospital (with eg an emergency department), falling within the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led community service was introduced in 2003 [12]. From April 2009, this was replaced with a new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in an attempt to address continuing health disparities [13]. The components of the DICI has been described in the previous publications [14]. The health district includes two other areas, Huntingdonshire and Greater Cambridge, which did not receive the full intermediate team and are able to serve as 'control' areas, although each hospital based service would have continued with its own internal service developments. We have previously reported no impact on metabolic control or hospitalisation rates in spite of full implementation of the service [6].

De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI contract commenced) and March 2012. Practice, patient age, elective/non elective status, ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes was considered present if E10-E14 was in any ICD10 field and, as the primary cause of admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009 were used as baseline, to compare with that recorded in 2011-2012 as the end of the intervention period. Using the Sarkadi et. al. method, the mean and standard deviation for normal distributions before and after the intervention can be estimated. The "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental **Error! Reference source not found.** left). In our study, 'health gain' represents the proportion

of patients with reduced inpatient payments between the baseline and intervention period. The reduction in commissioner payments reflects reduced needs in care and thus improvement in health.

Sarkadi's method has outlined ways to calculate the impact when the two distributions have the same standard deviation (SD), or when the follow-up group has smaller mean and smaller SD at the same time. However we have noticed when using real data that the follow-up-group might have smaller mean but larger SD. To accommodate this situation, we have modified the Sarkadi's method as described in online supplemental technical appendix and online supplemental Figure 1. The health gain distributions are presented in online supplemental Figure-2 to illustrate the health gains at a population level.

In addition to the Normal distribution originally used in Sakadi's method, three other distributions, Gamma distribution, Log-Normal distribution and Normal distribution of log-transferred payment data were attempted to fit the data. The goodness-of-fit statistics, Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-likelihood were tested over four distributions and the distribution with the minimum AIC, BIC and maximum log-likelihood was chosen as the final distribution to examine the impact.

Bootstrapping is used to obtain a p value for the probability of health gain larger than zero. We randomly sampled data points with replacements from the original data separately for the baseline and follow-up, so that we obtain bootstrapped data with the same numbers of data points. These are used to obtain an estimation of the health gain

after perturbation. This process is repeated 1000 times. The probability of observing estimations less than or equal to zero is calculated, and used as the approximation of the p value for testing whether health gain is significantly larger than zero.

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. Age data were provided allowing analyses to be undertaken above and below the median age (70 years) to assess any related variation.

The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

All analyses were conducted in R [Version 3.1]. Ethics approval was received from the National Research Ethics Service Committee- East of England.

Results

The sample size of inpatient payment records during the baseline and the intervention period in each region is presented in Table 1. The inpatient payments during the baseline period and the intervention period are shown in Table 2 by area and age group. In each area and age group, a lower individual median inpatient payment was more likely to be found in the intervention period.

Figure-1 shows the distribution of the inpatient payments in people with type 2 diabetes in the baseline and intervention periods. This illustrates the effect of the integrated care intervention, as the left-moving curve in the intervention period indicates the potential inpatient payment saving at a population level.

Four distribution (Normal distribution, Gamma distribution, Log-Normal distribution and Normal distribution of log-transformed payment data) were attempted to fit the payment data as presented in Supplemental Table 1. The Normal distribution of log-transformed payment data was chosen to estimate the impact on the intervention for its minimum AIC and BIC and its maximum log-likelihood.

The magnitude of the intervention at the population level is presented in Table-3. Significant `health gain' was observed both in the intervention area and control areas, especially among patients aged less than 70 years. In the intervention area, East Cambridge and Fenland, 7.69% (95 Confidence Interval (CI) 5.89-9.74%) and 2.05% (0.72 to 4.13%) of patients aged less than 70 years and aged more than 70 years, respectively had a reduced inpatient payment, compared with the population in the baseline period. In Huntingdonshire, the `health gain' was 6.90% (5.63 to 8.68%) and 4.62% (2.22 to 7.23%) among patients aged less than 70 years and patients aged more than 70 years, respectively. In Greater Cambridge, the `health gain' was 7.59% (5.63 to 9.94%) and 2.49% (1.46 to 4.58%) among patients aged less than 70 years and patients aged more than 70 years, respectively.

To allow comparisons, the estimated impact, based on a Normal distribution, is presented in Supplemental Table 2. In the intervention area, East Cambridge and Fenland, 2.74% (1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment, compared with the population in the baseline period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in 3.20 (1.77 to 7.20) % of patients aged less than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively. Significant 'health gain' was not identified within the population in Huntingdonshire over the study period.

Discussion

We have used a novel way, calculating the total health gain (proportion of people with reduced inpatient payments) assuming a Gaussian distribution, to assess the results of integrated care in the diabetic population of areas in Cambridgeshire through a population lens. The study revealed a possible effect of the new integrated care approach on inpatient payments, as 7.7% of patients aged less than 70 years and 2.1% of patients aged more than 70 years had reduced inpatient payments in the intervention area, East Cambridge and Fenland. However, reductions were also seen in the control areas, in Huntingdonshire, 6.9% of patients aged less than 70 years and 4.6 % of patients aged less than 70years had reduced inpatient payment; in Greater Cambridge, 7.6% of patients aged less than 70 years and 2.5 % of patients aged less than 70years had reduced inpatient. The 95% confidence intervals overlapped across the 3 areas, so we have not shown any differences between the areas.

Significant improvements in diabetes care can occur with multifaceted interventions [17] including disease management in the US [18] and integrated care in Germany [19] and these can be associated with reductions in hospital costs [20]. The integrated care intervention was successfully implemented across the area, with positive patient experience, improved practice nurse clinical confidence, and early reports of clinical benefit [13, 14, 21]. It is therefore surprising that although some (small) positive benefit was observed in the intervention area, the return on the investment of GBP250,000 was not greater and possibly less than in one of the control areas. Elsewhere, diabetes integrated care interventions have generally been more effective within single providers

or in contexts where multiple primary care organisations work with a single specialist provider under an integrated insurance scheme [6]. The integrated care intervention carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie payments) to hospital outpatients. This philosophy, rather than progressing to truly integrated services carried through the intervention period, albeit as part of a wider programme that included 'vertical integration' developments. It was perhaps to be expected that attempts at creating such greater 'vertical' integration in information management, clinical governance, budget and overall management were agreed but not implemented, actions more achievable within a single organization. There was an attempt to create a single equal partner network model [22] nearing the end of the intervention period, but this as not funded by the local commissioners.

The failure to implement integrated information management, almost certainly contributed to communication and integration difficulties. Most integrated care initiatives attempt to include data sharing [23] and this was not possible within the local information governance arrangements. This was noticed by the patients and was a source of frustration. Interestingly, integration was perceived as happening when there was one person 'fronting up' for all those involved. Case management has been proposed as one approach to integration, and requires the case manager to corral and coordinate the services for a given individual [18].

Whether our findings are due to a unique set of circumstances, or expected as part of a 3 compartment model (primary care, intermediate care, and secondary care) is unclear, but there are indications that the circumstances are not special. There are calls for more integration and less fragmentation in health care [23], yet the evidence on what works in England is limited [24, 25]. The latest changes in commissioning in the English NHS, with emphasis on the need to consider 'Any qualified Provider' in service delivery, and

associated market procurement approaches, could well impair the quality of diabetes care while increasing overall cost, if the experience here is reproduced elsewhere.

Similarly, as a 'natural experiment', it was not possible to measure the impact of integrated care on inpatient payments at an individual level. Instead, we estimated the proportion of the population showing 'heath gain' (reduced inpatient payments) from the integrated care intervention by using the distribution curve of inpatient payment. Although the method was within the conceptual framework proposed by Sakardi, some modifications to the methodology were made to overcome methodological drawbacks, for example requiring the same standard deviation for two Gaussian curves: something unlikely to occur in real scenarios. We believe this revised method would be more applicable to evaluate the 'health gain' for interventions at a population level.

There are limitations to our study. This was not a randomised trials, so any changes could be due to secular trends, although we do compare with the two other areas in Cambridgeshire. The data depended on the completeness of the coding of diabetes, and there being no systematic change in coding over this time period. We found that at least one provider had high diabetes ascertainment [10]. Data access restrictions prevented adjustment for some important co-variables. As the data used was record- rather than individual based, repeat inpatient records were unable to be linked, however, the record-based data still provides a range of plausible estimations. Moreover, within a relatively fixed diabetes population served by a local 'closed' inpatient care and tariff system, the likelihood for patients having a second hospital admission, would still be relatively low (although higher than those without diabetes) [10]. In other words, inpatient payments at two time-points are considered completely independent of each other. We acknowledge that this current analysis still yields findings subject to confounding bias unable to be measured in this study. The 'impact' observed in our study may therefore

only reflect measured changes in the DICI and 'control' regions respectively, rather than due to the DICI itself, as the DICI care model was not randomly assigned. As a result of data access restrictions, it is not possible in this study to identify those with multiple admissions (and payments) that would provide 'redundant information'. The application of bootstrapping ignoring such redundant information might lead to a mis-application of Sarkadi's tool and might inadvertently increase the false positive rate: something to be taken into consideration when interpreting the findings in this study. There might be other potential unidentified confounders in this study and evaluation seeking other confounding factors would be possible in future studies with more variables in the dataset including a way to identify those confounders.

In conclusion, we have applied a modified novel strategy to measure 'health gain' associated with an integrated care intervention at a population level. We found that there were no differences in inpatient payments. Our findings suggest that irrespective of the ideal principles behind integration, linking multiple health providers to deliver population based diabetes care is complex and improvements in health outcomes remain difficult to achieve.

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Contributors

D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods and revised the manuscript; Y.C. validated the method and re-analysed the data independently; Z.Z. designed the analysis framework and revised manuscript; D.S. designed the study, revised the analysis framework, revised the manuscript and interpreted the findings.

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Competing interests

None declared.

Ethics approval

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient payment in people with type 2 diabetes and possible effects of an integrated care on the curve.

The differences between the respective areas under the curve are shaded. Health gains for participants with lower inpatient payment.
Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.

Table 1: Sample size of the inpatient payment records

	East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
	<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	2012	2028	1494	1664	1575	1329
2011-2012	2431	2756	1871	1990	2004	1823

Table 2. Distribution of age and inpatient payment among people with type 2 diabetes by region and year

		East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
		<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	**Age,year**	60 (51, 65)	78 (74, 82)	61 (52, 65)	77 (73, 83)	58 (48, 64)	78 (74, 82)
	Inpatient payment, £	819 (506, 1860)	911 (531, 2473)	808 (504, 1707)	808 (531, 2251)	933 (597, 1997)	1151 (611, 2638)
2011-2012	**Age,year**	60 (51, 65)	78 (74, 83)	60 (48, 66)	77 (73, 83)	59 (50, 66)	79 (75, 84)
	Inpatiment payment, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

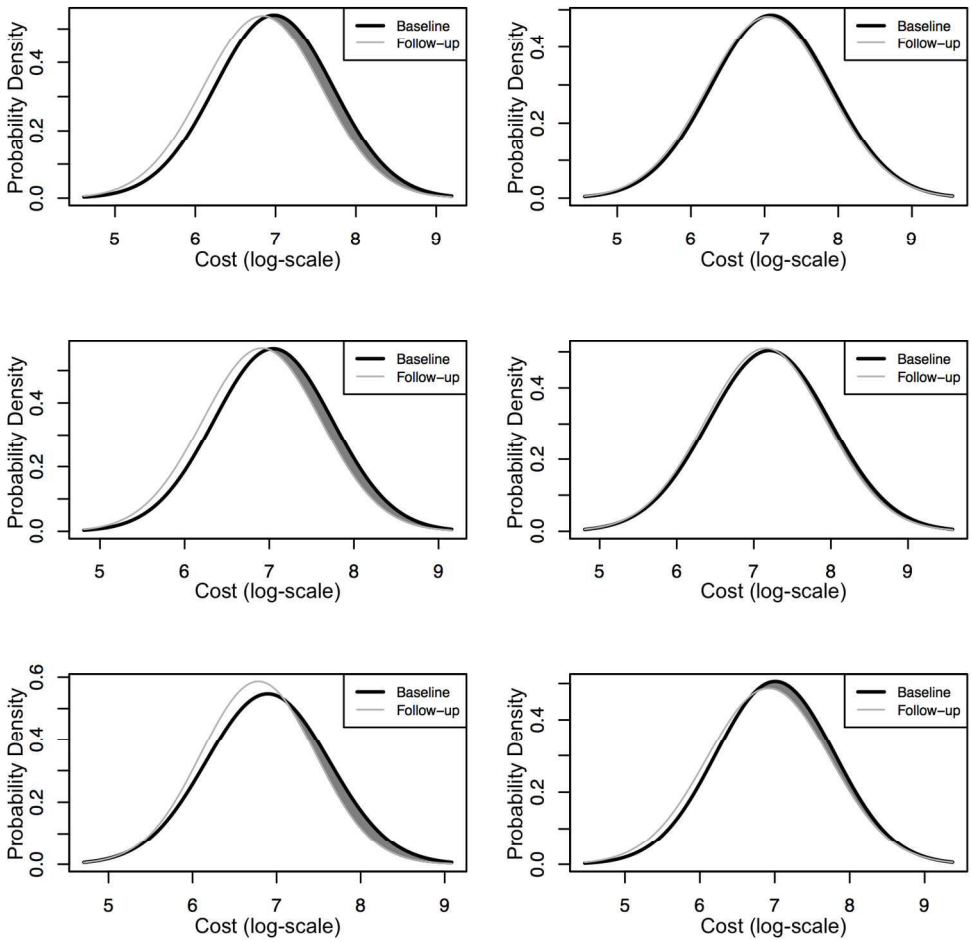
The median (inter-quartile rage (IQR)) was presented both for age and inpatient payment.

Table 3. The estimated absolute 'health gain (impact)' after the intervention by age and region: estimation based on Normal distribution of log transferred inpatient payment data

		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	7.69	5.89, 9.74)	0
	≥70 years	2.05	(0.72 , 4.13)	0.044796

Huntingdonshire	< 70 years	6.90	(5.63, 8.68)	0
	≥70 years	4.62	(2.22, 7.23)	0.001300
Greater Cambridge	< 70 years	7.59	(5.63, 9.94)	0
	≥70 years	2.49	(1.46, 4.58)	0.037096

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the integrated care at population level.



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Title: Population-level impact of diabetes integrated care on payments for inpatient care among people with type 2 diabetes in Cambridgeshire

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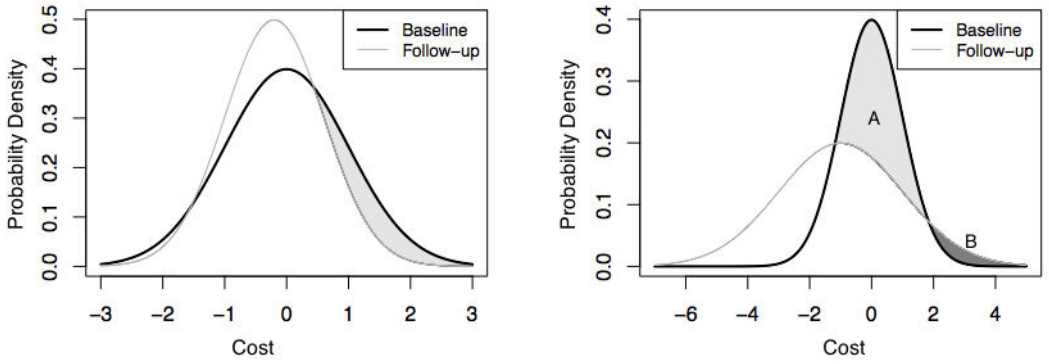
Online supplemental Technical Appendix

Estimating intervention impact, and confidence interval estimation

Sarkadi et. al. described a method to assess the population-level impact of interventions using normal distributions to approximate the actual data. After estimating the mean and standard deviation for the normal distributions before and after intervention, the "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental Figure 1 below).

Online supplemental Figure 1. Normal distribution curves.



To estimate the confidence interval, Sarkadi et. al. proposed to start from estimating the confidence intervals of mean and standard deviation for the two normal distributions. The point estimation of the mean for the baseline is μ_1, and the lower and higher bounds of the confidence interval at a certain level (for example, 95% confidence interval) are μ_{1min} and μ_{1max}, respectively; the estimation of standard deviation at baseline is σ_1, and the two bounds of confidence interval are σ_{1min} and σ_{1max}. Similarly, for the follow-up data, point estimations are μ_2 and σ_2, and the confidence bounds for them as μ_{2min}, μ_{2max}, and σ_{2min}, σ_{2max}. Denote the health gain as a function of the parameters for the two normal distributions as F (μ_1, σ_1,,μ_2,σ_2). Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as MIN(F (μ_{1min}, σ_{1max},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2min},σ_{2max})), and MAX(F (μ_{1max}, σ_{1min},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2max},σ_{2min})).

Modification of the impact estimation

There are a few situations where the original estimation algorithm is ambiguous.

When using real data to estimate parameters for the two normal distributions, it is unlikely that the two curves have the same standard deviation. In this case, the two curves will have to crossover points.

(1) If the two distributions are shown as in the left graph in Supplemental Figure 1, where the density of the follow-up is always lower compared to the baseline when observed data is larger than the larger of the two crossover points, it is easy to get the health gain estimation as the shaded area.

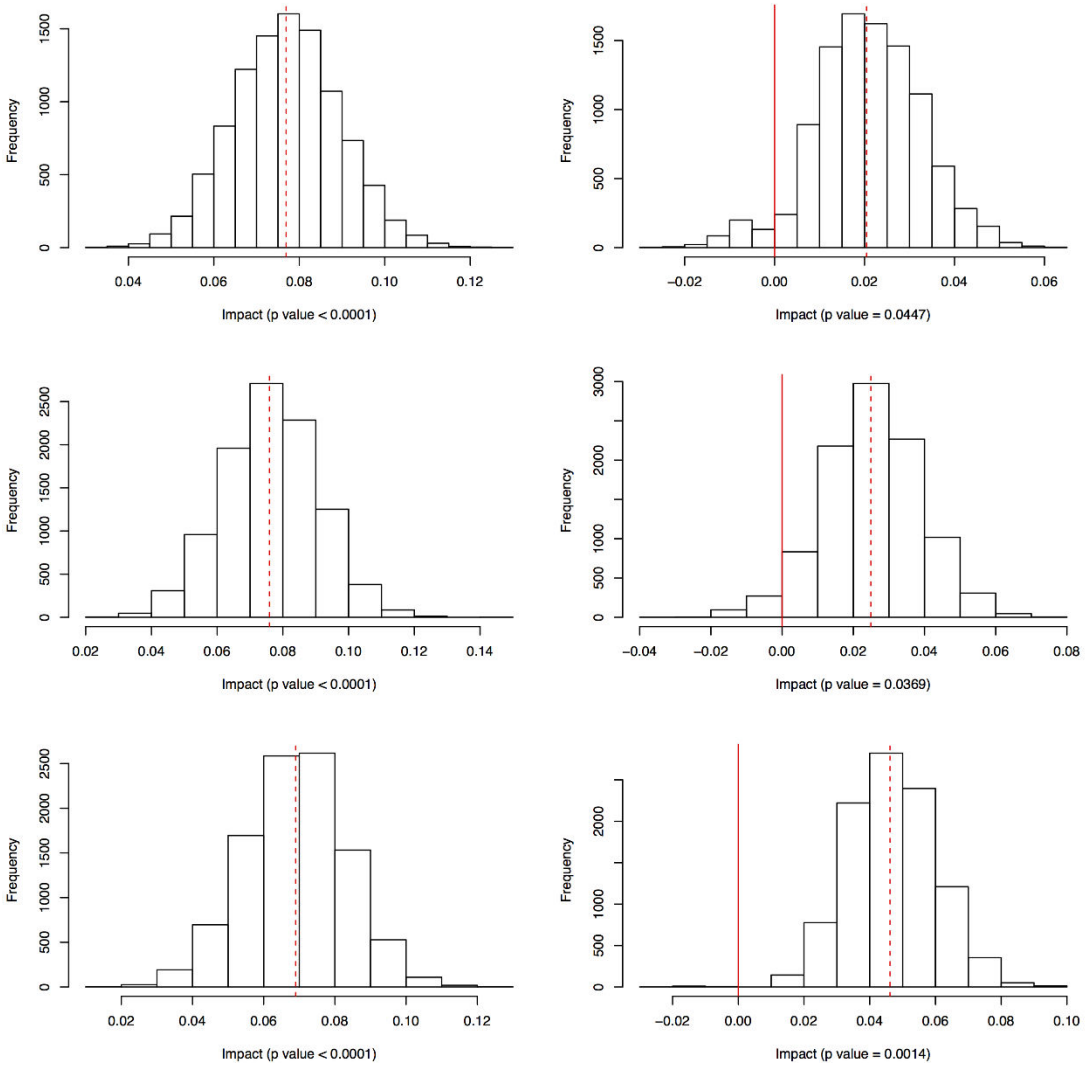
(2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear definition of the health gain. Here, we will define it as the difference of the two shaded areas A and B.

(3) The original method only discussed the case where the estimated mean after intervention is no larger than that of the baseline. We need to define health gain estimation even though this is not true, so that we can have negative estimations when calculating confidence intervals. If the estimated mean after intervention increases, we switch the places of the two curves to estimate a positive health gain as previously, and then put a negative sign to this value and take it as the negative health gain.

Online supplemental Figure 2. The health gain (impact) distribution

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the 3 year integrated care at population level. Distributions of the impact were approximated by bootstrapping. Subjects and their associated inpatient payment were selected by random resampling with replacement from the original data for 10000 times, and the impact was calculated in each resampled dataset. Dashed red line shows the impact in original data. Bootstrap p value was calculated by comparing the impact estimated in the resampled data to 0 (indicated by the solid red line; null hypothesis H0: impact<=0, and alternative hypothesis H1: impact>0; P = [Percentage with impact <= 0]).

Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.



Online supplemental Table 1. Goodness-of-fit statistics for Normal, Gamma, and log-normal distribution

		Normal distribution (log transformed inpatient payment)	Gamma distribution	Log Normal distribution	Normal distribution
		AIC			
East Cambridge and Fenland, 2008-2009	< 70 years	4138.08	4649.35	4413.18	5757.95
	≥70 years	4792.04	5639.68	5494.05	6648.18
East Cambridge and Fenland, 2011-2012	< 70 years	5125.91	5195.19	4799.82	6792.39
	≥70 years	6555.80	7541.19	7287.31	9014.41
Huntingdonshire, 2008-2009	< 70 years	3088.09	3592.87	3350.03	4603.81
	≥70 years	3063.47	3475.19	3319.11	4247.04
Huntingdonshire, 2011-2012	< 70 years	3910.41	4434.23	4070.55	5843.54
	≥70 years	4335.50	4634.40	4371.58	5835.11
Greater Cambridge, 2008-2009	< 70 years	2987.32	3506.21	3376.34	4203.61
	≥70 years	3739.02	4733.66	4663.78	5406.49
Greater Cambridge, 2011-2012	< 70 years	3647.87	4031.53	3784.87	5082.50
	≥70 years	4398.30	5438.64	5317.42	6307.03
		BIC			
East Cambridge and Fenland, 2008-2009	< 70 years	4149.13	4660.40	4424.23	5769.00
	≥70 years	4803.20	5650.85	5505.21	6659.34
East Cambridge and Fenland, 2011-2012	< 70 years	5137.38	5206.66	4811.29	6803.86
	≥70 years	6567.57	7552.96	7299.08	9026.18
Huntingdonshire, 2008-2009	< 70 years	3398.76	3603.54	3360.70	4614.48
	≥70 years	3073.81	3485.52	3329.44	4257.37
Huntingdonshire, 2011-2012	< 70 years	3921.50	4445.39	4081.71	5854.70
	≥70 years	4346.46	4645.37	4382.55	5846.08
Greater Cambridge, 2008-2009	< 70 years	2997.81	3516.70	3386.83	4214.09
	≥70 years	3749.75	4744.38	4674.50	5417.21
Greater Cambridge, 2011-2012	< 70 years	3658.76	4042.44	3795.77	5093.41
	≥70 years	4409.37	5449.71	5328.49	6318.10

		Log likelihood			
Overall					
East Cambridge and Fenland, 2008-2009	< 70 years	-2067.04	-2322.67	-2204.59	-2876.97
	≥70 years	-2394.02	-2817.84	-2745.02	-3322.09
East Cambridge and Fenland, 2011-2012	< 70 years	-2560.95	-2595.59	-2397.91	-3394.19
	≥70 years	-3275.90	-3768.59	-3641.66	-4505.20
Huntingdonshire, 2008-2009	< 70 years	-1692.05	-1794.44	-1673.01	-2299.90
	≥70 years	-1529.74	-1735.59	-1657.55	-2121.52
Huntingdonshire, 2011-2012	< 70 years	-1953.21	-2215.12	-2033.28	-2919.77
	≥70 years	-2165.75	-2315.20	-2183.79	-2915.56
Greater Cambridge, 2008-2009	< 70 years	-1491.66	-1751.11	-1686.17	-2099.80
	≥70 years	-1867.51	-2364.83	-2329.89	-2701.24
Greater Cambridge, 2011-2012	< 70 years	-1821.93	-2013.77	-1890.43	-2539.25
	≥70 years	-2197.15	-2717.32	-2656.71	-3151.51

AIC, Akaike information criterion; *BIC,* Bayesian information criterion.

Online supplemental Table 2. The estimated absolute 'health gain (impact)' after the intervention by age and region: estimation based on Normal-distribution

		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	1.58	(-1.91, 4.88)	0.051948
	≥70 years	2.74	(1.29 , 5.81)	0.014985
Huntingdonshire	< 70 years	1.83	(-2.44, 5.87)	0.220779
	≥70 years	-2.06	(-5.54, 3.79)	0.737263
Greater Cambridge	< 70 years	3.20	(1.77, 7.20)	0.004995
	≥70 years	4.14	(2.27, 7.86)	0.000999

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the integrated care at population level.

CHEERS Checklist

Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section	Item No	Recommendation	Reported on page No/line No
Title and Abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page-1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page-2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Page-4
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 4-5
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 5
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 5
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 5
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Page 5
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	Page 5
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 5-6
Measurement of effectiveness	11a	*Single study-based estimates*: Describe fully the design features of the single effectiveness study and why the single	Page 5-6

		study was a sufficient source of clinical effectiveness data.	
	11b	*Synthesis-based estimates*: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Page 6
Estimating resources and costs	13a	*Single study-based economic evaluation*: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation*: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Page 6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 6
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 6
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Page 6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 6
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 7
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If	Page 7

		applicable, report incremental cost-effectiveness ratios.	

Characterizing uncertainty	20a	*Single study-based economic evaluation*: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation*: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Page 7-8
Characterizing heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	Page 7-8
Discussion			
Study findings, limitations, generalizability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 8
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 13
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 13

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

The citation for the CHEERS Task Force Report is:
Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS)—Explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231-50.

BMJ Open

Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire: a post-intervention cohort follow up study

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Secondary Subject Heading:	Research methods
Keywords:	intergrated care, Diabetes, Intervention studies, Area under the curve

Title Page

Title: Population-level impact of diabetes integrated care on commissioner payments for inpatient care among people with type 2 diabetes in Cambridgeshire: a post-intervention cohort follow up study

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Words in the main text: 2,178

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Tables: 3

Figures: 1

References: 26

Online Appendix: 1

Keywords: Diabetes; Integrated care; Intervention studies; Area under the curve

Abstract

Objectives

Few studies have estimated the effect of diabetes integrated care at a population level. We have assessed the impact of introducing a community service led diabetes integrated care programme on commissioner payments (tariff) for inpatient care in rural England.

Methods

The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced community diabetes service, increasing specialist nursing, dietetic, podiatry and medical support to primary care and patients, while linking into other diabetes specialist services. Commissioner data was provided by the local authority. The difference in area between the two overlapping distribution curves of inpatient payments at baseline and follow-up (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient payments on a population level.

Results

Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of patients with diabetes aged more than 70 years in the Intervention area. However, reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two adjacent areas.

Conclusion

This enhanced community diabetes services was not associated with substantially reduced inpatient payments. Alternative diabetes integrated care approaches (eg with direct primary and secondary care collaboration rather than with a community service) should be tested.

Strengths and limitations of this study

- The 'health gain' in the revised method was clearly defined with a formulated algorithm of evaluation, which broadened the utilization scenarios especially when negative values were raised.
- The data used in this study depended upon the completeness of the coding for diabetes in the GP records. The impact of this potential ascertainment bias should have been steady as no systematic change in coding was known to have occurred over this time period.

Introduction

As the social and economic impact of diabetes grows, so does the variety of attempts to improve care quality and reduce health care costs among those affected [1, 2, 3, 4]. One approach, able to provide at least equivalent care to routine medical care with some types of patients, has been the introduction of nurses working within protocols, within medical services [5]. Other models known as 'intermediate care', including general practitioners with a special interest [6], and community diabetes nursing services [6] have been implemented, but without robust evaluation. As a proposed system, integrated care articulates all health workers and health systems around the needs of each patient and should be associated with improved outcomes and less cost [7].

However, the impact of a population based integrated care intervention is difficult to measure on an individual level. One randomised trial of an intermediate care service achieved minimal actual incremental benefit [8]. By their nature, randomised controlled trials are difficult to utilise when assessing the impact of a complete system change at a population level. . Sarkadi et al have proposed a method to look at population outcomes in their own right in the quest of understanding how interventions work at a population level [9]. Under the English National Health Service (NHS), public inpatient care is paid for from taxation through local commissioners. These payments do not generally cover the hospital costs of inpatients with diabetes [10], but can provide an NHS commissioner perspective that reflects both acuity and complexity, beyond eg length of stay. We have now used the Sarkadi approach to assess whether any changes in population based commissioner inpatient payment data occurred during a diabetes integrated care intervention by viewing the level and distribution of commissioner inpatient payments in the population as the unit of interest.

Methods

East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population 7,790) is largely rural, with a small number of socioeconomically deprived communities [6]. There is no local major hospital (with eg an emergency department), falling within the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led community service was introduced in 2003 [12]. From April 2009, this was replaced with a new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in an attempt to address continuing health disparities [13]. The components of the DICI has been described in the previous publications [14]. The health district includes two other areas, Huntingdonshire and Greater Cambridge, which did not receive the full intermediate team and are able to serve as 'control' areas, although each hospital based service would have continued with its own internal service developments. We have previously reported no impact on metabolic control or hospitalisation rates in spite of full implementation of the service [6].

De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI contract commenced) and March 2012. Practice, patient age, elective/non elective status, ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes was considered present if E10-E14 was in any ICD10 field and, as the primary cause of admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009 were used as baseline, to compare with that recorded in 2011-2012 as the end of the intervention period. Using the Sarkadi et. al. method, the mean and standard deviation for normal distributions before and after the intervention can be estimated. The "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental **Error! Reference source not found.**~~Figure 1~~ left). In our study, 'health gain' represents the

proportion of patients with reduced inpatient payments between the baseline and intervention period. The reduction in commissioner payments reflects reduced needs in care and thus improvement in health.

Sarkadi's method has outlined ways to calculate the impact when the two distributions have the same standard deviation (SD), or when the follow-up group has smaller mean and smaller SD at the same time. However we have noticed when using real data that the follow-up-group might have smaller mean but larger SD. To accommodate this situation, we have modified the Sarkadi's method as described in online supplemental technical appendix and online supplemental Figure 1. The health gain distributions are presented in online supplemental Figure-2 to illustrate the health gains at a population level.

In addition to the Normal distribution originally used in Sakadi's method, three other distributions, Gamma distribution, Log-Normal distribution and Normal distribution of log-transferred payment data were attempted to fit the data. The goodness-of-fit statistics, Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-likelihood were tested over four distributions and the distribution with the minimum AIC, BIC and maximum log-likelihood was chosen as the final distribution to examine the impact.

Bootstrapping is used to obtain a p value for the probability of health gain larger than zero. We randomly sampled data points with replacements from the original data separately for the baseline and follow-up, so that we obtain bootstrapped data with the same numbers of data points. These are used to obtain an estimation of the health gain

after perturbation. This process is repeated 1000 times. The probability of observing estimations less than or equal to zero is calculated, and used as the approximation of the p value for testing whether health gain is significantly larger than zero.

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. Age data were provided allowing analyses to be undertaken above and below the median age (70 years) to assess any related variation.

The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

All analyses were conducted in R [Version 3.1]. Ethics approval was received from the National Research Ethics Service Committee- East of England.

Results

The sample size of inpatient payment records during the baseline and the intervention period in each region is presented in Table 1. The inpatient payments during the baseline period and the intervention period are shown in Table 2 by area and age group. In each area and age group, a lower individual median inpatient payment was more likely to be found in the intervention period.

Figure-1 shows the distribution of the inpatient payments in people with type 2 diabetes in the baseline and intervention periods. This illustrates the effect of the integrated care intervention, as the left-moving curve in the intervention period indicates the potential inpatient payment saving at a population level.

Four distribution (Normal distribution, Gamma distribution, Log-Normal distribution and Normal distribution of log-transformed payment data) were attempted to fit the payment data as presented in Supplemental Table 1. The Normal distribution of log-transformed payment data was chosen to estimate the impact on the intervention for its minimum AIC and BIC and its maximum log-likelihood.

The magnitude of the intervention at the population level is presented in Table-3. Significant `health gain' was observed both in the intervention area and control areas, especially among patients aged less than 70 years. In the intervention area, East Cambridge and Fenland, 7.69% (95 Confidence Interval (CI) 5.89-9.74%) and 2.05% (0.72 to 4.13%) of patients aged less than 70 years and aged more than 70 years, respectively had a reduced inpatient payment, compared with the population in the baseline period. In Huntingdonshire, the `health gain' was 6.90% (5.63 to 8.68%) and 4.62% (2.22 to 7.23%) among patients aged less than 70 years and patients aged more than 70 years, respectively. In Greater Cambridge, the `health gain' was 7.59% (5.63 to 9.94%) and 2.49% (1.46 to 4.58%) among patients aged less than 70 years and patients aged more than 70 years, respectively.

To allow comparisons, the estimated impact, based on a Normal distribution, is presented in Supplemental Table 2. In the intervention area, East Cambridge and Fenland, 2.74% (1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment, compared with the population in the baseline period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in 3.20 (1.77 to 7.20) % of patients aged less than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively. Significant 'health gain' was not identified within the population in Huntingdonshire over the study period.

Discussion

We have used a novel way, calculating the total health gain (proportion of people with reduced inpatient payments) assuming a Gaussian distribution, to assess the results of integrated care in the diabetic population of areas in Cambridgeshire through a population lens. The study revealed a possible effect of the new integrated care approach on inpatient payments, as 7.7% of patients aged less than 70 years and 2.1% of patients aged more than 70 years had reduced inpatient payments in the intervention area, East Cambridge and Fenland. However, reductions were also seen in the control areas, in Huntingdonshire, 6.9% of patients aged less than 70 years and 4.6 % of patients aged less than 70years had reduced inpatient payment; in Greater Cambridge, 7.6% of patients aged less than 70 years and 2.5 % of patients aged less than 70years had reduced inpatient. The 95% confidence intervals overlapped across the 3 areas, so we have not shown any differences between the areas.

Significant improvements in diabetes care can occur with multifaceted interventions [17] including disease management in the US [18] and integrated care in Germany [19] and these can be associated with reductions in hospital costs [20]. The integrated care intervention was successfully implemented across the area, with positive patient experience, improved practice nurse clinical confidence, and early reports of clinical benefit [13, 14, 21]. It is therefore surprising that although some (small) positive benefit was observed in the intervention area, the return on the investment of GBP250,000 was not greater and possibly less than in one of the control areas. Elsewhere, diabetes integrated care interventions have generally been more effective within single providers

or in contexts where multiple primary care organisations work with a single specialist provider under an integrated insurance scheme [6]. The integrated care intervention carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie payments) to hospital outpatients. This philosophy, rather than progressing to truly integrated services carried through the intervention period, albeit as part of a wider programme that included 'vertical integration' developments. It was perhaps to be expected that attempts at creating such greater 'vertical' integration in information management, clinical governance, budget and overall management were agreed but not implemented, actions more achievable within a single organization. There was an attempt to create a single equal partner network model [22] nearing the end of the intervention period, but this as not funded by the local commissioners.

The failure to implement integrated information management, almost certainly contributed to communication and integration difficulties. Most integrated care initiatives attempt to include data sharing [23] and this was not possible within the local information governance arrangements. This was noticed by the patients and was a source of frustration. Interestingly, integration was perceived as happening when there was one person 'fronting up' for all those involved. Case management has been proposed as one approach to integration, and requires the case manager to corral and coordinate the services for a given individual [18].

Whether our findings are due to a unique set of circumstances, or expected as part of a 3 compartment model (primary care, intermediate care, and secondary care) is unclear, but there are indications that the circumstances are not special. There are calls for more integration and less fragmentation in health care [23], yet the evidence on what works in England is limited [24, 25]. The latest changes in commissioning in the English NHS, with emphasis on the need to consider 'Any qualified Provider' in service delivery, and

associated market procurement approaches, could well impair the quality of diabetes care while increasing overall cost, if the experience here is reproduced elsewhere.

Similarly, as a 'natural experiment', it was not possible to measure the impact of integrated care on inpatient payments at an individual level. Instead, we estimated the proportion of the population showing 'heath gain' (reduced inpatient payments) from the integrated care intervention by using the distribution curve of inpatient payment. Although the method was within the conceptual framework proposed by Sakardi, some modifications to the methodology were made to overcome methodological drawbacks, for example requiring the same standard deviation for two Gaussian curves: something unlikely to occur in real scenarios. We believe this revised method would be more applicable to evaluate the 'health gain' for interventions at a population level.

There are limitations to our study. This was not a randomised trials, so any changes could be due to secular trends, although we do compare with the two other areas in Cambridgeshire. The data depended on the completeness of the coding of diabetes, and there being no systematic change in coding over this time period. We found that at least one provider had high diabetes ascertainment [10]. Data access restrictions prevented adjustment for some important co-variables. As the data used was record- rather than individual based, repeat inpatient records were unable to be linked, however, the record-based data still provides a range of plausible estimations. Moreover, within a relatively fixed diabetes population served by a local 'closed' inpatient care and tariff system, the likelihood for patients having a second hospital admission, would still be relatively low (although higher than those without diabetes) [10]. In other words, inpatient payments at two time-points are considered completely independent of each other. We acknowledge that this current analysis still yields findings subject to confounding bias unable to be measured in this study. The 'impact' observed in our study may therefore

only reflect measured changes in the DICI and 'control' regions respectively, rather than due to the DICI itself, as the DICI care model was not randomly assigned. As a result of data access restrictions, it is not possible in this study to identify those with multiple admissions (and payments) that would provide 'redundant information'. The application of bootstrapping ignoring such redundant information might lead to a mis-application of Sarkadi's tool and might inadvertently increase the false positive rate: something to be taken into consideration when interpreting the findings in this study. There might be other potential unidentified confounders in this study and evaluation seeking other confounding factors would be possible in future studies with more variables in the dataset including a way to identify those confounders.

In conclusion, we have applied a modified novel strategy to measure 'health gain' associated with an integrated care intervention at a population level. We found that there were no differences in inpatient payments. Our findings suggest that irrespective of the ideal principles behind integration, linking multiple health providers to deliver population based diabetes care is complex and improvements in health outcomes remain difficult to achieve.

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Contributors

D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods and revised the manuscript; Y.C. validated the method and re-analysed the data independently; Z.Z. designed the analysis framework and revised manuscript; D.S. designed the study, revised the analysis framework, revised the manuscript and interpreted the findings.

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Competing interests

None declared.

Ethics approval

No personal identifiers were released to researchers, and all subsequent analyses were conducted on anonymised datasets. The work had approval from the Cambridgeshire research ethics committee as part of a wider service evaluation and, as such, was deemed not to require personal informed consent.

Provenance and peer review

Not commissioned; externally peer reviewed.

Data sharing statement

No additional data are available.

Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient payment in people with type 2 diabetes and possible effects of an integrated care on the curve.

The differences between the respective areas under the curve are shaded. Health gains for participants with lower inpatient payment.
Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.

Table 1: Sample size of the inpatient payment records

	East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
	<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	2012	2028	1494	1664	1575	1329
2011-2012	2431	2756	1871	1990	2004	1823

Table 2. Distribution of age and inpatient payment among people with type 2 diabetes by region and year

		East Cambridge and Fenland		Huntingdonshire		Great Cambridge	
		<70 years	≥70 years	<70 years	≥70 years	<70 years	≥70 years
2008-2009	**Age,year**	60 (51, 65)	78 (74, 82)	61 (52, 65)	77 (73, 83)	58 (48, 64)	78 (74, 82)
	Inpatient payment, £	819 (506, 1860)	911 (531, 2473)	808 (504, 1707)	808 (531, 2251)	933 (597, 1997)	1151 (611, 2638)
2011-2012	**Age,year**	60 (51, 65)	78 (74, 83)	60 (48, 66)	77 (73, 83)	59 (50, 66)	79 (75, 84)
	Inpatiment payment, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

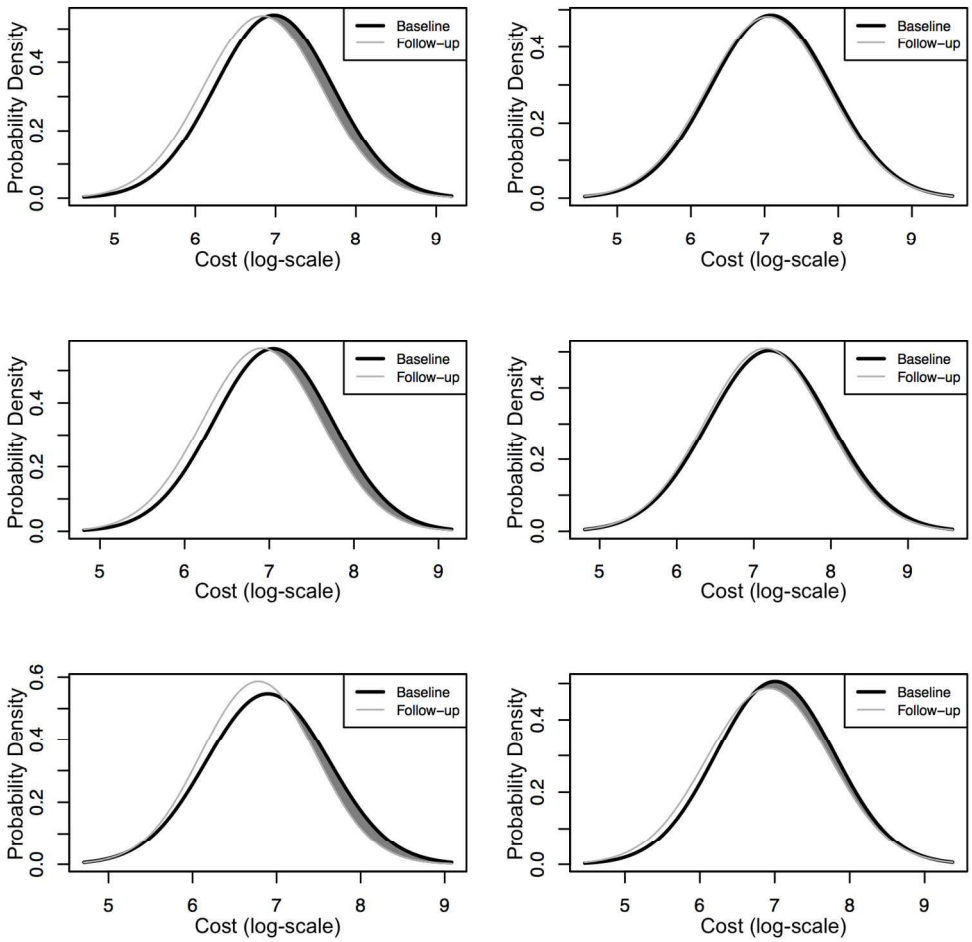
The median (inter-quartile rage (IQR)) was presented both for age and inpatient payment.

Table 3. The estimated absolute 'health gain (impact)' after the intervention by age and region: estimation based on Normal distribution of log transferred inpatient payment data

		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	7.69	5.89, 9.74)	0
	≥70 years	2.05	(0.72 , 4.13)	0.044796

Huntingdonshire	< 70 years	6.90	(5.63, 8.68)	0
	≥70 years	4.62	(2.22, 7.23)	0.001300
Greater Cambridge	< 70 years	7.59	(5.63, 9.94)	0
	≥70 years	2.49	(1.46, 4.58)	0.037096

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the integrated care at population level.



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Title: Population-level impact of diabetes integrated care on payments for inpatient care among people with type 2 diabetes in Cambridgeshire

Authors: Dahai Yu [1,2], Wei Yang [1,3] , Yamei Cai [1], Zhanzheng Zhao [1*], David Simmons [4*]

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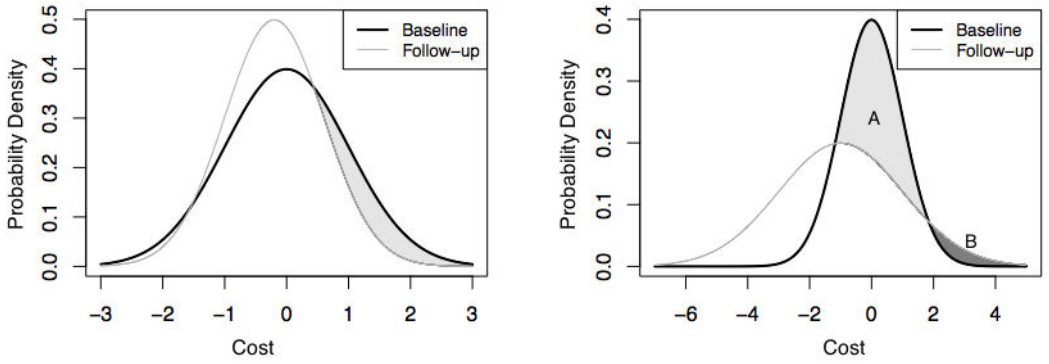
Online supplemental Technical Appendix

Estimating intervention impact, and confidence interval estimation

Sarkadi et. al. described a method to assess the population-level impact of interventions using normal distributions to approximate the actual data. After estimating the mean and standard deviation for the normal distributions before and after intervention, the "health gain" is defined as the area between the two distribution curves on the right side, where the distribution density after intervention is lower (the shaded area in supplemental Figure 1 below).

Online supplemental Figure 1. Normal distribution curves.



To estimate the confidence interval, Sarkadi et. al. proposed to start from estimating the confidence intervals of mean and standard deviation for the two normal distributions. The point estimation of the mean for the baseline is μ_1, and the lower and higher bounds of the confidence interval at a certain level (for example, 95% confidence interval) are μ_{1min} and μ_{1max}, respectively; the estimation of standard deviation at baseline is σ_1, and the two bounds of confidence interval are σ_{1min} and σ_{1max}. Similarly, for the follow-up data, point estimations are μ_2 and σ_2, and the confidence bounds for them as μ_{2min}, μ_{2max}, and σ_{2min}, σ_{2max}. Denote the health gain as a function of the parameters for the two normal distributions as F (μ_1, σ_1,,μ_2,σ_2). Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as MIN(F (μ_{1min}, σ_{1max},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2min},σ_{2max})), and MAX(F (μ_{1max}, σ_{1min},,μ_2,σ_2), F (μ_1, σ_1,,μ_{2max},σ_{2min})).

Modification of the impact estimation

There are a few situations where the original estimation algorithm is ambiguous.

When using real data to estimate parameters for the two normal distributions, it is unlikely that the two curves have the same standard deviation. In this case, the two curves will have to crossover points.

(1) If the two distributions are shown as in the left graph in Supplemental Figure 1, where the density of the follow-up is always lower compared to the baseline when observed data is larger than the larger of the two crossover points, it is easy to get the health gain estimation as the shaded area.

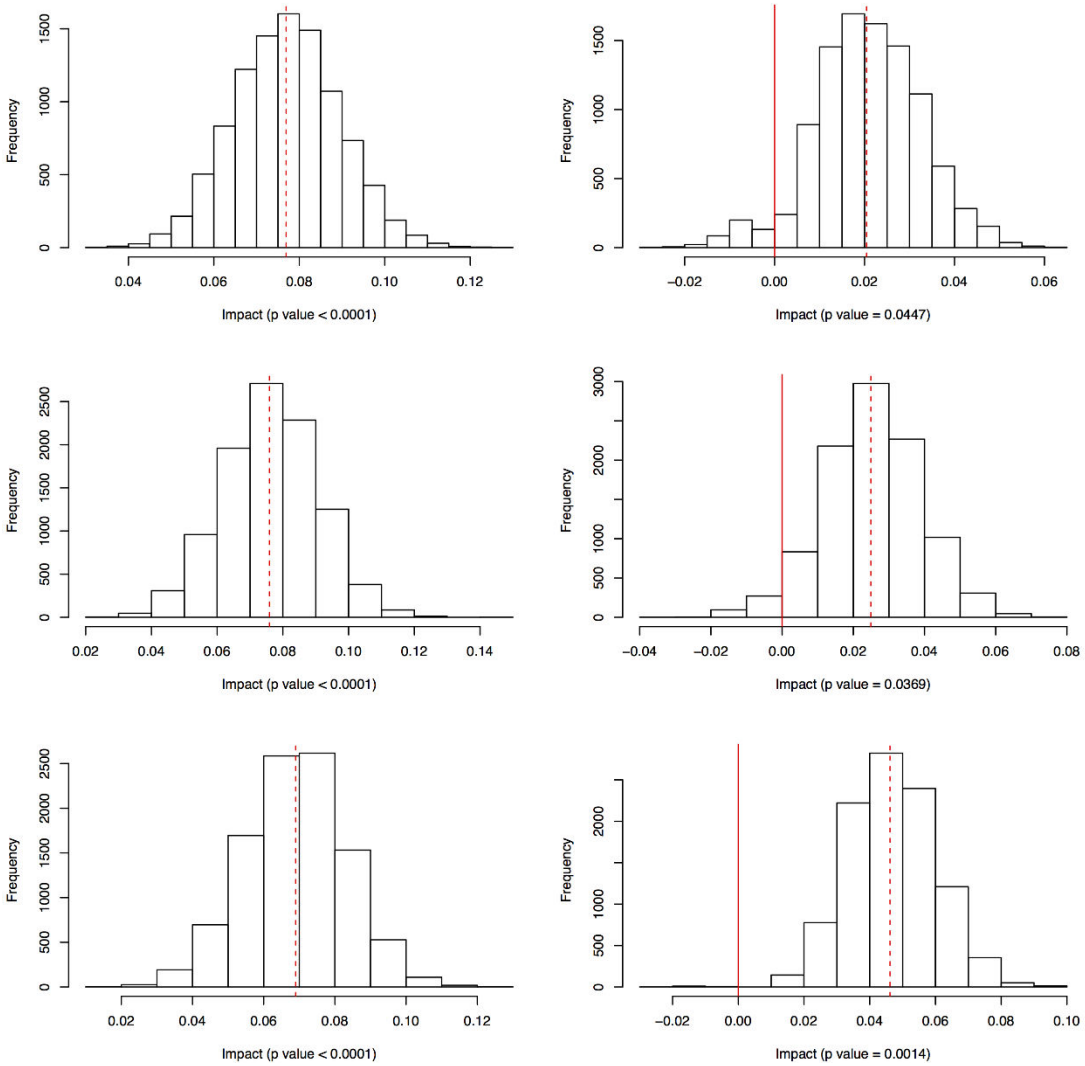
(2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear definition of the health gain. Here, we will define it as the difference of the two shaded areas A and B.

(3) The original method only discussed the case where the estimated mean after intervention is no larger than that of the baseline. We need to define health gain estimation even though this is not true, so that we can have negative estimations when calculating confidence intervals. If the estimated mean after intervention increases, we switch the places of the two curves to estimate a positive health gain as previously, and then put a negative sign to this value and take it as the negative health gain.

Online supplemental Figure 2. The health gain (impact) distribution

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the 3 year integrated care at population level. Distributions of the impact were approximated by bootstrapping. Subjects and their associated inpatient payment were selected by random resampling with replacement from the original data for 10000 times, and the impact was calculated in each resampled dataset. Dashed red line shows the impact in original data. Bootstrap p value was calculated by comparing the impact estimated in the resampled data to 0 (indicated by the solid red line; null hypothesis H0: impact<=0, and alternative hypothesis H1: impact>0; P = [Percentage with impact <= 0]).

Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;
Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;
Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.



Online supplemental Table 1. Goodness-of-fit statistics for Normal, Gamma, and log-normal distribution

		Normal distribution (log transformed inpatient payment)	Gamma distribution	Log Normal distribution	Normal distribution
		AIC			
East Cambridge and Fenland, 2008-2009	< 70 years	4138.08	4649.35	4413.18	5757.95
	≥70 years	4792.04	5639.68	5494.05	6648.18
East Cambridge and Fenland, 2011-2012	< 70 years	5125.91	5195.19	4799.82	6792.39
	≥70 years	6555.80	7541.19	7287.31	9014.41
Huntingdonshire, 2008-2009	< 70 years	3088.09	3592.87	3350.03	4603.81
	≥70 years	3063.47	3475.19	3319.11	4247.04
Huntingdonshire, 2011-2012	< 70 years	3910.41	4434.23	4070.55	5843.54
	≥70 years	4335.50	4634.40	4371.58	5835.11
Greater Cambridge, 2008-2009	< 70 years	2987.32	3506.21	3376.34	4203.61
	≥70 years	3739.02	4733.66	4663.78	5406.49
Greater Cambridge, 2011-2012	< 70 years	3647.87	4031.53	3784.87	5082.50
	≥70 years	4398.30	5438.64	5317.42	6307.03
		BIC			
East Cambridge and Fenland, 2008-2009	< 70 years	4149.13	4660.40	4424.23	5769.00
	≥70 years	4803.20	5650.85	5505.21	6659.34
East Cambridge and Fenland, 2011-2012	< 70 years	5137.38	5206.66	4811.29	6803.86
	≥70 years	6567.57	7552.96	7299.08	9026.18
Huntingdonshire, 2008-2009	< 70 years	3398.76	3603.54	3360.70	4614.48
	≥70 years	3073.81	3485.52	3329.44	4257.37
Huntingdonshire, 2011-2012	< 70 years	3921.50	4445.39	4081.71	5854.70
	≥70 years	4346.46	4645.37	4382.55	5846.08
Greater Cambridge, 2008-2009	< 70 years	2997.81	3516.70	3386.83	4214.09
	≥70 years	3749.75	4744.38	4674.50	5417.21
Greater Cambridge, 2011-2012	< 70 years	3658.76	4042.44	3795.77	5093.41
	≥70 years	4409.37	5449.71	5328.49	6318.10

		Log likelihood			
Overall					
East Cambridge and Fenland, 2008-2009	< 70 years	-2067.04	-2322.67	-2204.59	-2876.97
	≥70 years	-2394.02	-2817.84	-2745.02	-3322.09
East Cambridge and Fenland, 2011-2012	< 70 years	-2560.95	-2595.59	-2397.91	-3394.19
	≥70 years	-3275.90	-3768.59	-3641.66	-4505.20
Huntingdonshire, 2008-2009	< 70 years	-1692.05	-1794.44	-1673.01	-2299.90
	≥70 years	-1529.74	-1735.59	-1657.55	-2121.52
Huntingdonshire, 2011-2012	< 70 years	-1953.21	-2215.12	-2033.28	-2919.77
	≥70 years	-2165.75	-2315.20	-2183.79	-2915.56
Greater Cambridge, 2008-2009	< 70 years	-1491.66	-1751.11	-1686.17	-2099.80
	≥70 years	-1867.51	-2364.83	-2329.89	-2701.24
Greater Cambridge, 2011-2012	< 70 years	-1821.93	-2013.77	-1890.43	-2539.25
	≥70 years	-2197.15	-2717.32	-2656.71	-3151.51

AIC, Akaike information criterion; *BIC,* Bayesian information criterion.

Online supplemental Table 2. The estimated absolute 'health gain (impact)' after the intervention by age and region: estimation based on Normal-distribution

		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	1.58	(-1.91, 4.88)	0.051948
	≥70 years	2.74	(1.29 , 5.81)	0.014985
Huntingdonshire	< 70 years	1.83	(-2.44, 5.87)	0.220779
	≥70 years	-2.06	(-5.54, 3.79)	0.737263
Greater Cambridge	< 70 years	3.20	(1.77, 7.20)	0.004995
	≥70 years	4.14	(2.27, 7.86)	0.000999

The health gain (impact) was defined as percentage of people with type 2 diabetes and hospital admission having reduced inpatient payment after the integrated care at population level.

CHEERS Checklist

Items to include when reporting economic evaluations of health interventions

The **ISPOR CHEERS Task Force Report**, *Consolidated Health Economic Evaluation Reporting Standards (CHEERS)—Explanation and Elaboration: A Report of the ISPOR Health Economic Evaluations Publication Guidelines Good Reporting Practices Task Force*, provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

Section	Item No	Recommendation	Reported on page No/line No
Title and Abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page-1
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page-2
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Page-4
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 4-5
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 5
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 5
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 5
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Page 5
Discount rate	9	Report the choice of discount rate(s) used for costs and outcomes and say why appropriate.	Page 5
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 5-6
Measurement of effectiveness	11a	*Single study-based estimates*: Describe fully the design features of the single effectiveness study and why the single	Page 5-6

		study was a sufficient source of clinical effectiveness data.	
	11b	*Synthesis-based estimates*: Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Page 6
Estimating resources and costs	13a	*Single study-based economic evaluation*: Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation*: Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Page 6
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 6
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 6
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Page 6
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 6
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 7
Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If	Page 7

		applicable, report incremental cost-effectiveness ratios.	

Characterizing uncertainty	20a	*Single study-based economic evaluation*: Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation*: Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Page 7-8
Characterizing heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	Page 7-8
Discussion			
Study findings, limitations, generalizability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 8
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 13
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 13

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

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