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

1
2
3 Abstract

4
5 **Objectives**

6 Few studies have estimated the impact of diabetes integrated care at a population level.
7 We have assessed the impact of introducing a community service led diabetes integrated
8 care programme on inpatient payments (tariff) in rural England.
9

10
11 **Methods**

12 The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced
13 community diabetes service, increasing specialist nursing, dietetic, podiatry and medical
14 support to primary care and patients, while linking into other diabetes specialist services.
15 Tariff data was provided by the local authority. The area between the two overlapping
16 distribution curves of inpatient cost at baseline and follow-up (at 3 years) was used to
17 estimate the impact of integrated care on inpatient payments on a population level.
18

19
20 **Results**

21 Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8)% of
22 patients with diabetes aged more than 70 years in the Intervention area. However,
23 reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20)% of patients aged <70
24 years and 4.1 (2.3 to 7.9)% of patients ≥aged more than 70 years in one of the two
25 adjacent areas.
26

27
28 **Conclusion**

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

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2
3 was replaced with a new Diabetes Integrated Care Initiative (DICI) using additional
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5 finance (£250,000 pa), in an attempt to address continuing health disparities [11]. The
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7 components of the DICI has been described in the previous publications [12]. The health
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9 district includes two other areas, Huntingdonshire and Greater Cambridge, which did not
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11 receive the full intermediate team and are able to serve as 'control' areas. .

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14 De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire
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16 were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI
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18 contract commenced) and March 2012. Practice, patient age, elective/non elective status,
19
20 ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes
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22 was considered present if E10-E14 was in any ICD10 field and, as the primary cause of
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24 admission if coded in the first field [13, 14]. Inpatient payments recorded in 2008-2009
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26 were used as baseline, to compare with that recorded in 2011-2012 as the end of the
27
28 intervention period. Using the Sarkadi et. al. method, the mean and standard deviation
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30 for normal distributions before and after the intervention can be estimated. The "health
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32 gain" is defined as the area between the two distribution curves on the right side, where
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34 the distribution density after intervention is lower (the shaded area in supplemental **Error!**
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36 **Reference source not found.** left). In our study, the 'health gain' represents the
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38 proportion of patients with reduced inpatient payments between the baseline and
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40 intervention period. However when using real data to estimate parameters for two
41
42 normal distributions, it is unlikely that the two curves have the same standard deviation.
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44 In our case, the two curves will have crossover points. To overcome this, we have
45
46 modified the Sarkadi's method as described in supplemental technical appendix 1.

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49 Bootstrapping is used to obtain a p value for the probability of health gain larger than
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51 zero. We randomly sampled data points with replacements from the original data
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53 separately for the baseline and follow-up, so that we obtain bootstrapped data with the
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3 same numbers of data points. These are used to obtain an estimation of the health gain
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5 after perturbation. This process is repeated 1000 times. The probability of observing
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7 estimations less than or equal to zero is calculated, and used as the approximation of the
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9 p value for testing whether health gain is significantly larger than zero.
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11
12 No personal identifiers were released to researchers, and all subsequent analyses were
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14 conducted on anonymised datasets. The work had approval from the Cambridgeshire
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16 research ethics committee as part of a wider service evaluation and, as such, was deemed
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18 not to require personal informed consent.
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21 All analyses were conducted in R [Version 3.1]. Ethics approval was received from the
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23 National Research Ethics Service Committee- East of England.
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32 Results

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34 The inpatient payments during the baseline period and the intervention period are shown
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36 in Table 1 by area and age group. In each area and age group, a lower individual median
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38 inpatient payment was more likely to be found in the intervention period.
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40
41 Figure-2 shows the distribution of the inpatient payments in people with type 2 diabetes
42
43 in the baseline and intervention periods. This illustrates the effect of the integrated care
44
45 intervention, as the left-moving curve in the intervention period indicates the potential
46
47 inpatient payment saving at a population level. The magnitude of the intervention at the
48
49 population level is presented in Table-2. In the intervention area, East Cambridge and
50
51 Fenland, 2.74% (95 Confidence Interval (CI) 1.29 to 5.81%) of patients aged more than 70
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53 years had a reduced inpatient payment, compared with the population in the baseline
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55 period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in
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3 3.20 (1.77 to 7.20)% of patients aged less than 70 years and 4.14 (2.27 to 7.86)% patients
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5 aged more than 70 years, respectively. Significant 'health gain' was not identified within
6
7 the population in Huntingdonshire over the study period. The health gain distributions
8
9 are presented in supplemental Figure-2 to illustrate the health gains at a population level.
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11 **Discussion**

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15 We have used a novel way, calculating the total health gain (proportion of people with
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17 reduced inpatient payments) assuming a Gaussian distribution, to assess the results of
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19 integrated care in the diabetic population of areas in Cambridgeshire through a
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21 population lens. The study revealed a possible limited effect of the new integrated care
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23 approach on inpatient payments, as 2.7% of patients aged more than 70 years had
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25 reduced inpatient payments in the intervention area, East Cambridge and Fenland.
26
27 However, reductions were also seen in one of the control areas, Greater Cambridge,
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29 where inpatient payments were not only reduced in those age over 70 years (4.1%), but
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31 also among those aged less than 70 years (3.2%). However, the 95% confidence intervals
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33 overlapped across the 3 areas, so we have not shown any differences between the areas.
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41 Significant improvements in diabetes care can occur with multifaceted interventions [15]
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43 including disease management in the US [16] and integrated care in Germany [17] and
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45 these can be associated with reductions in hospital costs [18]. The integrated care
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47 intervention was successfully implemented across the area, with positive patient
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49 experience, improved practice nurse clinical confidence, and early reports of clinical
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51 benefit [11, 12, 19]. It is therefore surprising that although some (small) positive benefit
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53 was observed in the intervention area, the return on the investment of GBP250,000 was
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55 not greater and possibly less than in one of the control areas. Elsewhere, diabetes
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3 integrated care interventions have generally been more effective within single providers
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5 or in contexts where multiple primary care organisations work with a single specialist
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7 provider under an integrated insurance scheme [5]. The integrated care intervention
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9 carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie
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11 payments) to hospital outpatients. This philosophy, rather than progressing to truly
12
13 integrated services carried through the intervention period. It was perhaps to be
14
15 expected that attempts at creating greater integration in information management,
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17 clinical governance, budget and overall management were agreed but not implemented,
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19 actions more achievable within a single organization. There was an attempt to create a
20
21 single equal partner network model [20] nearing the end of the intervention period, but
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23 this as not funded by the local commissioners.
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26
27 The failure to implement integrated information management, almost certainly
28
29 contributed to communication and integration difficulties. Most integrated care
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31 initiatives attempt to include data sharing [21] and this was not possible within the local
32
33 information governance arrangements. This was noticed by the patients and was a
34
35 source of frustration. Interestingly, integration was perceived as happening when there
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37 was one person 'fronting up' for all those involved. Case management has been proposed
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39 as one approach to integration, and requires the case manager to corral and coordinate
40
41 the services for a given individual [16].
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46 Whether our findings are due to a unique set of circumstances, or expected as part of a 3
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48 compartment model (primary care, intermediate care, and secondary care) is unclear, but
49
50 there are indications that the circumstances are not special. There are calls for more
51
52 integration and less fragmentation in health care [21], yet the evidence on what works in
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54 England is limited [22, 23]. The latest changes in commissioning in the English NHS, with
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56 emphasis on the need to consider 'Any qualified Provider' in service delivery, and
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3 associated market procurement approaches, could well impair the quality of diabetes
4 care while increasing overall cost, if the experience here is reproduced elsewhere.
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8 Similarly, as a 'natural experiment', it was not possible to measure the impact of
9
10 integrated care on inpatient payments at an individual level. Instead, we estimated the
11
12 proportion of the population showing 'health gain' (reduced inpatient payments) from
13
14 the integrated care intervention by using the distribution curve of inpatient payment.
15
16 Although the method was within the conceptual framework proposed by Sakardi, some
17
18 modifications to the methodology were made to overcome methodological drawbacks,
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20 for example requiring the same standard deviation for two Gaussian curves: something
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22 unlikely to occur in real scenarios. We believe this revised method would be more
23
24 applicable to evaluate the 'health gain' for interventions at a population level.
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28 There are limitations to our study. This was not a randomised trials, so any changes could
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30 be due to secular trends, although we do compare with the two other areas in
31
32 Cambridgeshire. The data depended on the completeness of the coding of diabetes, and
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34 there being no systematic change in coding over this time period. We found that at least
35
36 one provider had high diabetes ascertainment [24].
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40 In conclusion, we have applied a modified novel strategy to measure 'health gain'
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42 associated with an integrated care intervention at a population level. We found that
43
44 there were no differences in inpatient payments. Our findings suggest that irrespective of
45
46 the ideal principles behind integration, linking multiple health providers to deliver
47
48 population based diabetes care is complex and improvements in health outcomes remain
49
50 difficult to achieve.
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53 54 55 56 **References** 57 58 59 60

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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.

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3 **Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient cost in**
4 **people with type 2 diabetes and possible effects of an integrated care on the curve.**
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7 *The differences between the respective areas under the curve are shaded. Health gains for*
8 *participants with lower inpatient cost.*

9 *Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;*

10 *Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;*

11 *Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.*
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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)

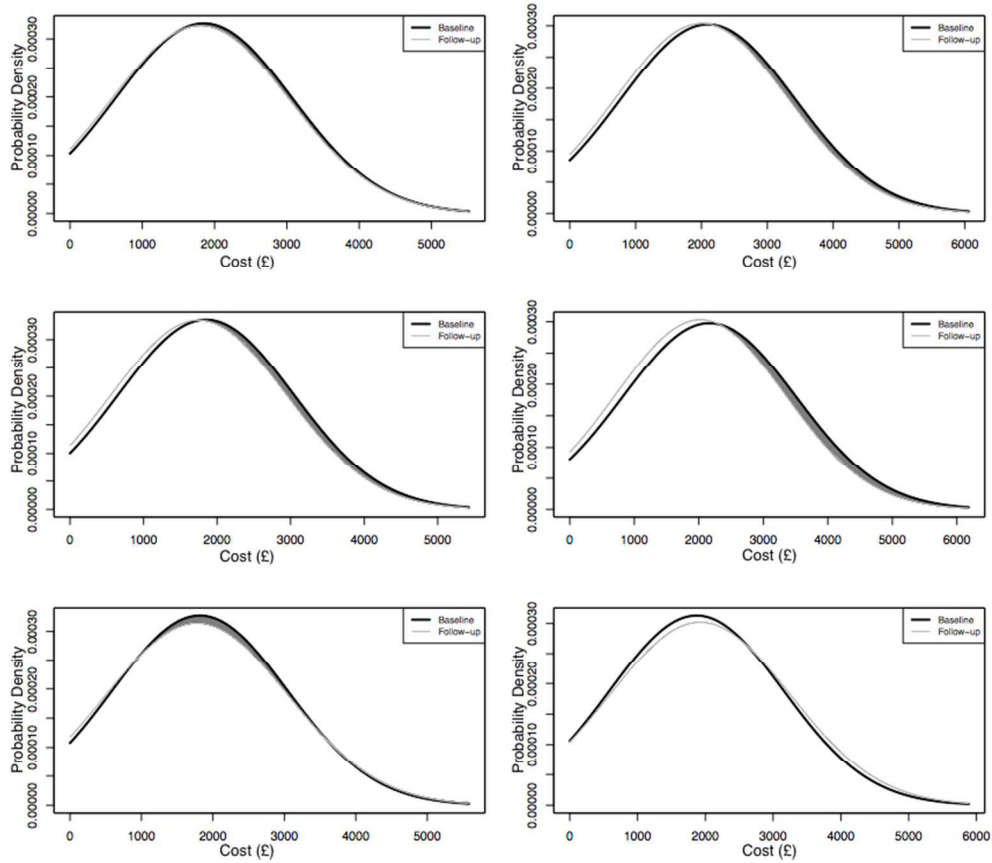
The median (inter-quartile range (IQR)) was presented both for age and cost.

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 health cost after the integrated care at population level.

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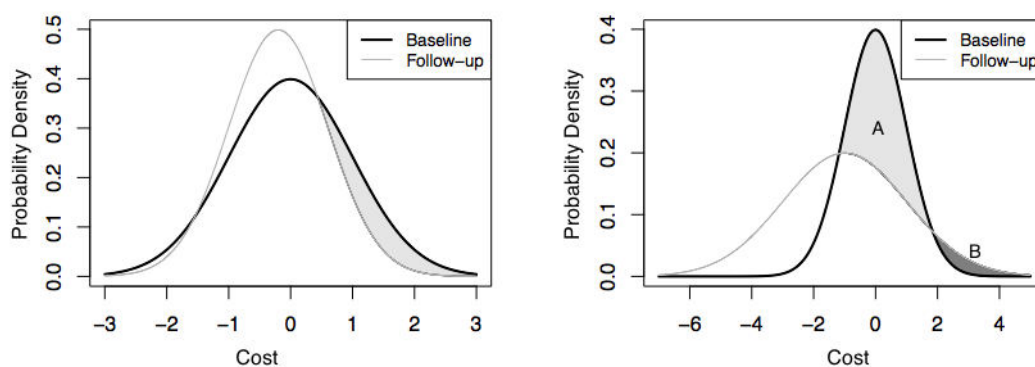
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Online supplemental 1: Technical Appendix

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 $F(\mu_1, \sigma_1, \mu_2, \sigma_2)$. Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as $\text{MIN}(F(\mu_{1min}, \sigma_{1max}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2min}, \sigma_{2max}))$, and $\text{MAX}(F(\mu_{1max}, \sigma_{1min}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2max}, \sigma_{2min}))$.

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.

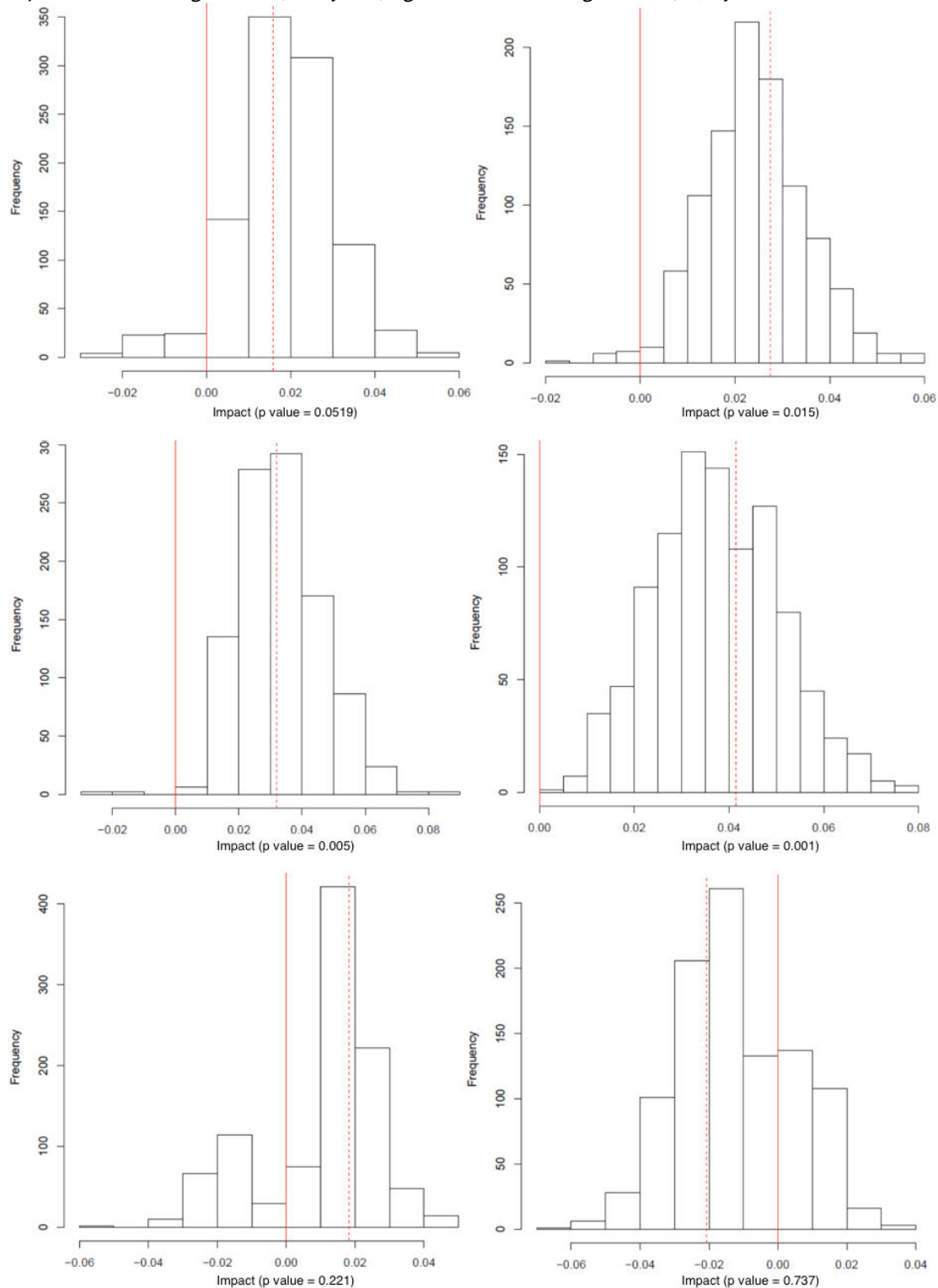
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- (2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear 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.

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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 health 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) <i>Cohort study</i> —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) <i>Cohort study</i> —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

1
2 supplemental.

3 (c) Explain how missing data were addressed

4 Response: Not applicable. Any inpatient income of each patient in the intervention
5 area and control was recorded by CCG as described on page 5.

6
7 (d) Cohort study—If applicable, explain how loss to follow-up was addressed

8 Response: It was described in the method section as defined as the financial year of
9 the CCG audit team on page 5.

10 (e) Describe any sensitivity analyses

11 Response: the analysis were repeated in the age-stratification and verified by
12 bootstrapping on page 5 and 6.

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15 Continued on next page

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Results

Participants	13*	<p>(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</p> <p>Response: As the evaluation at population level, there was no information at individual level was used in this study as described on page 6.</p> <p>(b) Give reasons for non-participation at each stage</p> <p>Response: Not applicable.</p> <p>(c) Consider use of a flow diagram</p> <p>Response: Not applicable.</p>
Descriptive data	14*	<p>(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders</p> <p>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.</p> <p>(b) Indicate number of participants with missing data for each variable of interest</p> <p>Response: Not applicable.</p> <p>(c) <i>Cohort study</i>—Summarise follow-up time (eg, average and total amount)</p> <p>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.</p>
Outcome data	15*	<p><i>Cohort study</i>—Report numbers of outcome events or summary measures over time</p> <p>Response: It was described in table-1 on page 13.</p>
Main results	16	<p>(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</p> <p>Response: The health gain was described in table-2 with confidence interval tested by bootstrapping on page 13.</p> <p>(b) Report category boundaries when continuous variables were categorized</p> <p>Response: Not applicable.</p> <p>(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period</p> <p>Response: Not applicable.</p>
Other analyses	17	<p>Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses</p> <p>Response: Not applicable.</p>
Discussion		
Key results	18	<p>Summarise key results with reference to study objectives</p> <p>Response: It was described in the page-8.</p>
Limitations	19	<p>Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias</p> <p>Response: It was described in the page-9.</p>
Interpretation	20	<p>Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence</p> <p>Response: It was described in the page-9.</p>

1
2 Generalisability 21 Discuss the generalisability (external validity) of the study results

3 Response: It was described in the page-9.

4 **Other information**

5
6 Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable,
7 for the original study on which the present article is based

8 Response: It was described in the page-11.

9 *Give information separately for cases and controls in case-control studies and, if applicable, for exposed and
10 unexposed groups in cohort and cross-sectional studies.
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13 **Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and
14 published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely
15 available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at
16 <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is
17 available at www.strobe-statement.org.
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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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Primary Subject Heading:	Diabetes and endocrinology
Secondary Subject Heading:	Research methods
Keywords:	intergrated care, Diabetes, Intervention studies, Area under the curve

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Manuscripts

1
2
3 **Title Page**

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

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43 Words in the main text: 2,178

44 Words in the abstract: 222

45 Tables: 3

46 Figures: 1

47 References: 26

48 Online Appendix: 1

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

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1
2
3 1 Abstract

4 2 **Objectives**

5 3 Few studies have estimated the effect of diabetes integrated care at a population level.
6 4 We have assessed the impact of introducing a community service led diabetes integrated
7 5 care programme on commissioner payments (tariff) for inpatient care in rural England.

8
9
10 6 **Methods**

11 7 The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced
12 8 community diabetes service, increasing specialist nursing, dietetic, podiatry and medical
13 9 support to primary care and patients, while linking into other diabetes specialist services.
14 10 Commissioner data was provided by the local authority. The difference in area between
15 11 the two overlapping distribution curves of inpatient payments at baseline and follow-up
16 12 (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient
17 13 payments on a population level.

18
19
20 14 **Results**

21 15 Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of
22 16 patients with diabetes aged more than 70 years in the Intervention area. However,
23 17 reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70
24 18 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two
25 19 adjacent areas.

26
27 20 **Conclusion**

28
29 21 This enhanced community diabetes services was not associated with substantially
30 22 reduced inpatient payments. Alternative diabetes integrated care approaches (eg with
31 23 direct primary and secondary care collaboration rather than with a community service)
32 24 should be tested.

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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.

1 **Introduction**

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

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

25 **Methods**

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3 1 East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population
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5 2 7,790) is largely rural, with a small number of socioeconomically deprived communities
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7 3 [6]. There is no local major hospital (with eg an emergency department), falling within
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9 4 the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have
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11 5 been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led
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13 6 community service was introduced in 2003 [12]. From April 2009, this was replaced with a
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15 7 new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in
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17 8 an attempt to address continuing health disparities [13]. The components of the DICI has
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19 9 been described in the previous publications [14]. The health district includes two other
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21 10 areas, Huntingdonshire and Greater Cambridge, which did not receive the full
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23 11 intermediate team and are able to serve as ‘control’ areas, although each hospital based
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25 12 service would have continued with its own internal service developments. We have
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27 13 previously reported no impact on metabolic control or hospitalisation rates in spite of full
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29 14 implementation of the service [6].
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33 15 De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire
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35 16 were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI
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37 17 contract commenced) and March 2012. Practice, patient age, elective/non elective status,
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39 18 ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes
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41 19 was considered present if E10-E14 was in any ICD10 field and, as the primary cause of
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43 20 admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009
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45 21 were used as baseline, to compare with that recorded in 2011-2012 as the end of the
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47 22 intervention period. Using the Sarkadi et. al. method, the mean and standard deviation
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49 23 for normal distributions before and after the intervention can be estimated. The “health
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51 24 gain” is defined as the area between the two distribution curves on the right side, where
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53 25 the distribution density after intervention is lower (the shaded area in supplemental **Error!**
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55 26 **Reference source not found.** left). In our study, ‘health gain’ represents the proportion
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1 of patients with reduced inpatient payments between the baseline and intervention
2 period. The reduction in commissioner payments is seen as a 'health gain', as under the
3 NHS, such liberation of public funds can be used elsewhere to achieve a gain in health.

4
5 Sarkadi's method has outlined ways to calculate the impact when the two distributions
6 have the same standard deviation (SD), or when the follow-up group has smaller mean
7 and smaller SD at the same time. However we have noticed when using real data that the
8 follow-up-group might have smaller mean but larger SD. To accommodate this situation,
9 we have modified the Sarkadi's method as described in supplemental technical appendix
10 1.

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

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

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3 1 All analyses were conducted in R [Version 3.1]. Ethics approval was received from the
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5 2 National Research Ethics Service Committee- East of England.
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13 **Results**

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15 6 The sample size of inpatient payment records during the baseline and the intervention
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17 7 period in each region is presented in Table 1. The inpatient payments during the baseline
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19 8 period and the intervention period are shown in Table 2 by area and age group. In each
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21 9 area and age group, a lower individual median inpatient payment was more likely to be
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23 10 found in the intervention period.
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27 11 Figure-1 shows the distribution of the inpatient payments in people with type 2 diabetes
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29 12 in the baseline and intervention periods. This illustrates the effect of the integrated care
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31 13 intervention, as the left-moving curve in the intervention period indicates the potential
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33 14 inpatient payment saving at a population level. The magnitude of the intervention at the
34
35 15 population level is presented in Table-3. In the intervention area, East Cambridge and
36
37 16 Fenland, 2.74% (95 Confidence Interval (CI) 1.29 to 5.81%) of patients aged more than 70
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39 17 years had a reduced inpatient payment, compared with the population in the baseline
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41 18 period. In one of the control areas, Greater Cambridge, 'health gain' was also observed in
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43 19 3.20 (1.77 to 7.20)% of patients aged less than 70 years and 4.14 (2.27 to 7.86)% patients
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45 20 aged more than 70 years, respectively. Significant 'health gain' was not identified within
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47 21 the population in Huntingdonshire over the study period. The health gain distributions
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49 22 are presented in supplemental Figure-2 to illustrate the health gains at a population level.
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52 23 The gamma-distribution and log-normal distribution was attempted to be applied in the
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54 24 study which did not significantly make improvement in fitting the data distributions. The
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3 1 G-computation [17] was also applied in the data and restricted by the data access, no
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5 2 significant changes was observed.
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10 4 **Discussion**

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14 6 We have used a novel way, calculating the total health gain (proportion of people with
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16 7 reduced inpatient payments) assuming a Gaussian distribution, to assess the results of
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18 8 integrated care in the diabetic population of areas in Cambridgeshire through a
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20 9 population lens. The study revealed a possible limited effect of the new integrated care
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22 10 approach on inpatient payments, as 2.7% of patients aged more than 70 years had
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24 11 reduced inpatient payments in the intervention area, East Cambridge and Fenland.
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26 12 However, reductions were also seen in one of the control areas, Greater Cambridge,
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28 13 where inpatient payments were not only reduced in those age over 70 years (4.1%), but
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30 14 also among those aged less than 70 years (3.2%). However, the 95% confidence intervals
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32 15 overlapped across the 3 areas, so we have not shown any differences between the areas.
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38 17 Significant improvements in diabetes care can occur with multifaceted interventions [18]
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40 18 including disease management in the US [19] and integrated care in Germany [20] and
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42 19 these can be associated with reductions in hospital costs [21]. The integrated care
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44 20 intervention was successfully implemented across the area, with positive patient
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46 21 experience, improved practice nurse clinical confidence, and early reports of clinical
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48 22 benefit [13, 14, 22]. It is therefore surprising that although some (small) positive benefit
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50 23 was observed in the intervention area, the return on the investment of GBP250,000 was
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52 24 not greater and possibly less than in one of the control areas. Elsewhere, diabetes
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54 25 integrated care interventions have generally been more effective within single providers
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3 1 or in contexts where multiple primary care organisations work with a single specialist
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5 2 provider under an integrated insurance scheme [6]. The integrated care intervention
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7 3 carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie
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9 4 payments) to hospital outpatients. This philosophy, rather than progressing to truly
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11 5 integrated services carried through the intervention period, albeit as part of a wider
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13 6 programme that included ‘vertical integration’ developments. It was perhaps to be
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15 7 expected that attempts at creating such greater ‘vertical’ integration in information
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17 8 management, clinical governance, budget and overall management were agreed but not
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19 9 implemented, actions more achievable within a single organization. There was an
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21 10 attempt to create a single equal partner network model [23] nearing the end of the
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23 11 intervention period, but this as not funded by the local commissioners.

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26 12 The failure to implement integrated information management, almost certainly
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28 13 contributed to communication and integration difficulties. Most integrated care
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30 14 initiatives attempt to include data sharing [24] and this was not possible within the local
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32 15 information governance arrangements. This was noticed by the patients and was a
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34 16 source of frustration. Interestingly, integration was perceived as happening when there
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36 17 was one person ‘fronting up’ for all those involved. Case management has been proposed
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38 18 as one approach to integration, and requires the case manager to corral and coordinate
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40 19 the services for a given individual [19].

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44 20 Whether our findings are due to a unique set of circumstances, or expected as part of a 3
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46 21 compartment model (primary care, intermediate care, and secondary care) is unclear, but
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48 22 there are indications that the circumstances are not special. There are calls for more
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50 23 integration and less fragmentation in health care [24], yet the evidence on what works in
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52 24 England is limited [25, 26]. The latest changes in commissioning in the English NHS, with
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54 25 emphasis on the need to consider ‘Any qualified Provider’ in service delivery, and

1 associated market procurement approaches, could well impair the quality of diabetes
2 care while increasing overall cost, if the experience here is reproduced elsewhere.
3 Similarly, as a 'natural experiment', it was not possible to measure the impact of
4 integrated care on inpatient payments at an individual level. Instead, we estimated the
5 proportion of the population showing 'health gain' (reduced inpatient payments) from
6 the integrated care intervention by using the distribution curve of inpatient payment.
7 Although the method was within the conceptual framework proposed by Sakardi, some
8 modifications to the methodology were made to overcome methodological drawbacks,
9 for example requiring the same standard deviation for two Gaussian curves: something
10 unlikely to occur in real scenarios. We believe this revised method would be more
11 applicable to evaluate the 'health gain' for interventions at a population level.

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

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3 1 only reflect measured changes in the DICI and 'control' regions respectively, rather than
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5 2 due to the DICI itself, as the DICI care model was not randomly assigned.
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7
8 3 In conclusion, we have applied a modified novel strategy to measure 'health gain'
9
10 4 associated with an integrated care intervention at a population level. We found that
11
12 5 there were no differences in inpatient payments. Our findings suggest that irrespective of
13
14 6 the ideal principles behind integration, linking multiple health providers to deliver
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16 7 population based diabetes care is complex and improvements in health outcomes remain
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18 8 difficult to achieve.
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44 The views expressed are those of the authors and not necessarily those of the NHS, the
45 NIHR or the Department of Health.

46 Contributors

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

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2
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4

5
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9 **5 Competing interests**
10

11 6 None declared.
12

13 **7 Ethics approval**
14

15
16 8 No personal identifiers were released to researchers, and all subsequent analyses were
17 9 conducted on anonymised datasets. The work had approval from the Cambridgeshire
18 10 research ethics committee as part of a wider service evaluation and, as such, was deemed
19 11 not to require personal informed consent.

20 **12 Provenance and peer review**
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24 13 Not commissioned; externally peer reviewed.
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26 **14 Data sharing statement**
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28 15 No additional data are available.
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3 **1 Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient cost in**
4 **2 people with type 2 diabetes and possible effects of an integrated care on the curve.**

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7 4 *The differences between the respective areas under the curve are shaded. Health gains for*
8 5 *participants with lower inpatient cost.*
9 6 *Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;*
10 7 *Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;*
11 8 *Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.*
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For peer review only

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 range (IQR)) was presented both for age and cost.

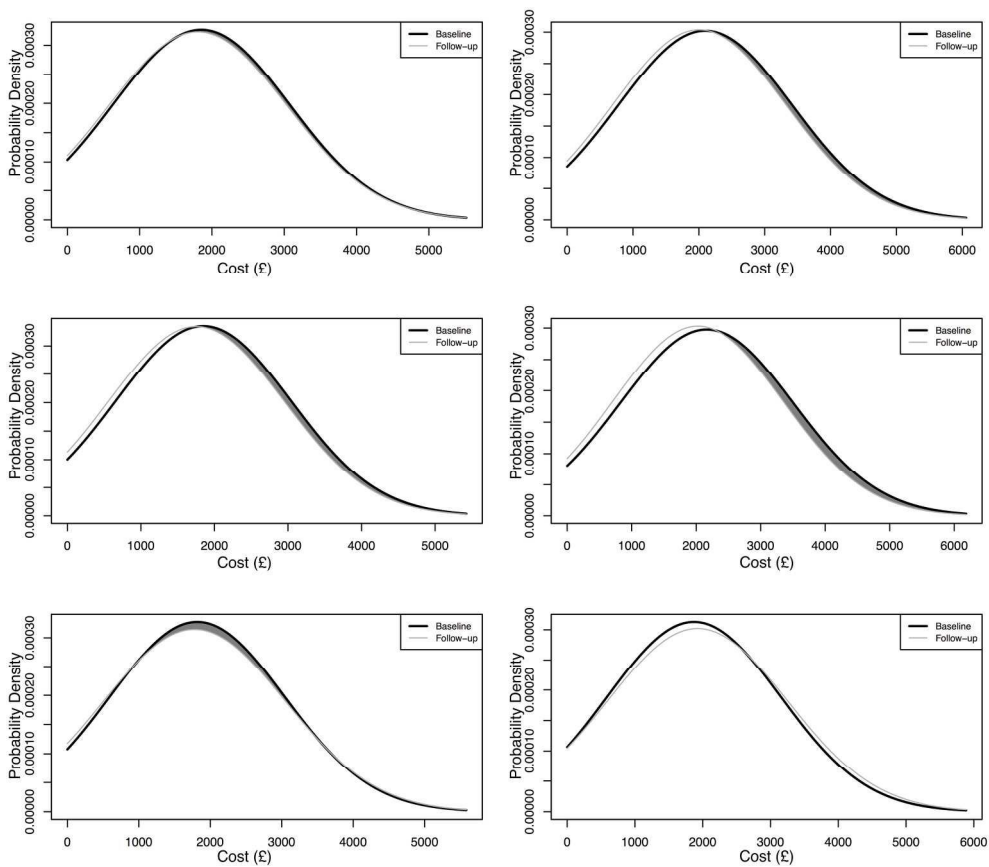
Table 3. The estimated absolute ‘health cost gain (impact)’ after the intervention by age and region

		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 health cost after the integrated care at population level.

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Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 1

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	<i>Single study-based estimates</i> : Describe fully the design features of the single effectiveness study and why the single	Page 5-6

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 2

		study was a sufficient source of clinical effectiveness data.	
	11b	<i>Synthesis-based estimates</i> : 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	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 3

		applicable, report incremental cost-effectiveness ratios.	
Characterizing uncertainty	20a	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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

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

SCHOLARONE™
Manuscripts

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3 **Title Page**

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

6 **Authors:** Dahai Yu ^{1,2}, Wei Yang ^{1,3}, Yamei Cai ¹, Zhanzheng Zhao ^{1*}, David Simmons
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45 Tables: 3

46 Figures: 1

47 References: 26

48 Online Appendix: 1

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

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1
2
3 1 Abstract

4 2 **Objectives**

5 3 Few studies have estimated the effect of diabetes integrated care at a population level.
6 4 We have assessed the impact of introducing a community service led diabetes integrated
7 5 care programme on commissioner payments (tariff) for inpatient care in rural England.

8
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10 6 **Methods**

11 7 The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced
12 8 community diabetes service, increasing specialist nursing, dietetic, podiatry and medical
13 9 support to primary care and patients, while linking into other diabetes specialist services.
14 10 Commissioner data was provided by the local authority. The difference in area between
15 11 the two overlapping distribution curves of inpatient payments at baseline and follow-up
16 12 (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient
17 13 payments on a population level.

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20 14 **Results**

21 15 Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of
22 16 patients with diabetes aged more than 70 years in the Intervention area. However,
23 17 reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70
24 18 years and 4.1 (2.3 to 7.9) % of patients ≥aged more than 70 years in one of the two
25 19 adjacent areas.

26
27 20 **Conclusion**

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29 21 This enhanced community diabetes services was not associated with substantially
30 22 reduced inpatient payments. Alternative diabetes integrated care approaches (eg with
31 23 direct primary and secondary care collaboration rather than with a community service)
32 24 should be tested.

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Strengths and limitations of this study

- This study used 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.

1 Introduction

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

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

25 Methods

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3 1 East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population
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5 2 7,790) is largely rural, with a small number of socioeconomically deprived communities
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7 3 [6]. There is no local major hospital (with eg an emergency department), falling within
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9 4 the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have
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11 5 been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led
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13 6 community service was introduced in 2003 [12]. From April 2009, this was replaced with a
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15 7 new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in
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17 8 an attempt to address continuing health disparities [13]. The components of the DICI has
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19 9 been described in the previous publications [14]. The health district includes two other
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21 10 areas, Huntingdonshire and Greater Cambridge, which did not receive the full
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23 11 intermediate team and are able to serve as ‘control’ areas, although each hospital based
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25 12 service would have continued with its own internal service developments. We have
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27 13 previously reported no impact on metabolic control or hospitalisation rates in spite of full
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29 14 implementation of the service [6].

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33 15 De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire
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35 16 were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI
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37 17 contract commenced) and March 2012. Practice, patient age, elective/non elective status,
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39 18 ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes
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41 19 was considered present if E10-E14 was in any ICD10 field and, as the primary cause of
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43 20 admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009
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45 21 were used as baseline, to compare with that recorded in 2011-2012 as the end of the
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47 22 intervention period. Using the Sarkadi et. al. method, the mean and standard deviation
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49 23 for normal distributions before and after the intervention can be estimated. The “health
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51 24 gain” is defined as the area between the two distribution curves on the right side, where
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53 25 the distribution density after intervention is lower (the shaded area in supplemental **Error!**
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55 26 **Reference source not found.** left). In our study, ‘health gain’ represents the proportion

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

4
5 Sarkadi's method has outlined ways to calculate the impact when the two distributions
6 have the same standard deviation (SD), or when the follow-up group has smaller mean
7 and smaller SD at the same time. However we have noticed when using real data that the
8 follow-up-group might have smaller mean but larger SD. To accommodate this situation,
9 we have modified the Sarkadi's method as described in online supplemental technical
10 appendix and online supplemental Figure 1. The health gain distributions are presented in
11 online supplemental Figure-2 to illustrate the health gains at a population level.

12
13 In addition to the Normal distribution originally used in Sakadi's method, three other
14 distributions, Gamma distribution, Log-Normal distribution and Normal distribution of
15 log-transferred payment data were attempted to fit the data. The goodness-of-fit
16 statistics, Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-
17 likelihood were tested over four distributions and the distribution with the minimum AIC,
18 BIC and maximum log-likelihood was chosen as the final distribution to examine the
19 impact.

20
21 Bootstrapping is used to obtain a p value for the probability of health gain larger than
22 zero. We randomly sampled data points with replacements from the original data
23 separately for the baseline and follow-up, so that we obtain bootstrapped data with the
24 same numbers of data points. These are used to obtain an estimation of the health gain

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

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

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

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

14 **Results**

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

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

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2
3 1 Four distribution (Normal distribution, Gamma distribution, Log-Normal distribution and
4
5 2 Normal distribution of log-transformed payment data) were attempted to fit the
6
7 3 payment data as presented in Supplemental Table 1. The Normal distribution of log-
8
9 4 transformed payment data was chosen to estimate the impact on the intervention for its
10
11 5 minimum AIC and BIC and its maximum log-likelihood.

12
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14 6 The magnitude of the intervention at the population level is presented in Table-3.
15
16 7 Significant 'health gain' was observed both in the intervention area and control areas,
17
18 8 especially among patients aged less than 70 years. In the intervention area, East
19
20 9 Cambridge and Fenland, 7.69% (95 Confidence Interval (CI) 5.89-9.74%) and 2.05% (0.72 to
21
22 10 4.13%) of patients aged less than 70 years and aged more than 70 years, respectively had a
23
24 11 reduced inpatient payment, compared with the population in the baseline period. In
25
26 12 Huntingdonshire, the 'health gain' was 6.90% (5.63 to 8.68%) and 4.62% (2.22 to 7.23%)
27
28 13 among patients aged less than 70 years and patients aged more than 70 years,
29
30 14 respectively. In Greater Cambridge, the 'health gain' was 7.59% (5.63 to 9.94%) and 2.49%
31
32 15 (1.46 to 4.58%) among patients aged less than 70 years and patients aged more than 70
33
34 16 years, respectively.

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38 17 To allow comparisons, the estimated impact, based on a Normal distribution, is presented
39
40 18 in Supplemental Table 2. In the intervention area, East Cambridge and Fenland, 2.74%
41
42 19 (1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment,
43
44 20 compared with the population in the baseline period. In one of the control areas, Greater
45
46 21 Cambridge, 'health gain' was also observed in 3.20 (1.77 to 7.20) % of patients aged less
47
48 22 than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively.
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50 23 Significant 'health gain' was not identified within the population in Huntingdonshire over
51
52 24 the study period.

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1

2 **Discussion**

3

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

16

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

1
2
3 1 or in contexts where multiple primary care organisations work with a single specialist
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5 2 provider under an integrated insurance scheme [6]. The integrated care intervention
6
7 3 carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie
8
9 4 payments) to hospital outpatients. This philosophy, rather than progressing to truly
10
11 5 integrated services carried through the intervention period, albeit as part of a wider
12
13 6 programme that included ‘vertical integration’ developments. It was perhaps to be
14
15 7 expected that attempts at creating such greater ‘vertical’ integration in information
16
17 8 management, clinical governance, budget and overall management were agreed but not
18
19 9 implemented, actions more achievable within a single organization. There was an
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21 10 attempt to create a single equal partner network model [22] nearing the end of the
22
23 11 intervention period, but this as not funded by the local commissioners.

24
25
26 12 The failure to implement integrated information management, almost certainly
27
28 13 contributed to communication and integration difficulties. Most integrated care
29
30 14 initiatives attempt to include data sharing [23] and this was not possible within the local
31
32 15 information governance arrangements. This was noticed by the patients and was a
33
34 16 source of frustration. Interestingly, integration was perceived as happening when there
35
36 17 was one person ‘fronting up’ for all those involved. Case management has been proposed
37
38 18 as one approach to integration, and requires the case manager to corral and coordinate
39
40 19 the services for a given individual [18].

41
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44 20 Whether our findings are due to a unique set of circumstances, or expected as part of a 3
45
46 21 compartment model (primary care, intermediate care, and secondary care) is unclear, but
47
48 22 there are indications that the circumstances are not special. There are calls for more
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50 23 integration and less fragmentation in health care [23], yet the evidence on what works in
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52 24 England is limited [24, 25]. The latest changes in commissioning in the English NHS, with
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54 25 emphasis on the need to consider ‘Any qualified Provider’ in service delivery, and

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3 1 associated market procurement approaches, could well impair the quality of diabetes
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5 2 care while increasing overall cost, if the experience here is reproduced elsewhere.
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7 3 Similarly, as a 'natural experiment', it was not possible to measure the impact of
8
9 4 integrated care on inpatient payments at an individual level. Instead, we estimated the
10
11 5 proportion of the population showing 'health gain' (reduced inpatient payments) from
12
13 6 the integrated care intervention by using the distribution curve of inpatient payment.
14
15 7 Although the method was within the conceptual framework proposed by Sakardi, some
16
17 8 modifications to the methodology were made to overcome methodological drawbacks,
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19 9 for example requiring the same standard deviation for two Gaussian curves: something
20
21 10 unlikely to occur in real scenarios. We believe this revised method would be more
22
23 11 applicable to evaluate the 'health gain' for interventions at a population level.
24
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26
27 12 There are limitations to our study. This was not a randomised trials, so any changes could
28
29 13 be due to secular trends, although we do compare with the two other areas in
30
31 14 Cambridgeshire. The data depended on the completeness of the coding of diabetes, and
32
33 15 there being no systematic change in coding over this time period. We found that at least
34
35 16 one provider had high diabetes ascertainment [10]. Data access restrictions prevented
36
37 17 adjustment for some important co-variables. As the data used was record- rather than
38
39 18 individual based, repeat inpatient records were unable to be linked, however, the record-
40
41 19 based data still provides a range of plausible estimations. Moreover, within a relatively
42
43 20 fixed diabetes population served by a local 'closed' inpatient care and tariff system, the
44
45 21 likelihood for patients having a second hospital admission, would still be relatively low
46
47 22 (although higher than those without diabetes) [10]. In other words, inpatient payments
48
49 23 at two time-points are considered completely independent of each other. We
50
51 24 acknowledge that this current analysis still yields findings subject to confounding bias
52
53 25 unable to be measured in this study. The 'impact' observed in our study may therefore
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3 1 only reflect measured changes in the DICI and ‘control’ regions respectively, rather than
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5 2 due to the DICI itself, as the DICI care model was not randomly assigned. As a result of
6
7 3 data access restrictions, it is not possible in this study to identify those with multiple
8
9 4 admissions (and payments) that would provide ‘redundant information’. The application
10
11 5 of bootstrapping ignoring such redundant information might lead to a mis-application of
12
13 6 Sarkadi’s tool and might inadvertently increase the false positive rate: something to be
14
15 7 taken into consideration when interpreting the findings in this study. There might be
16
17 8 other potential unidentified confounders in this study and evaluation seeking other
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19 9 confounding factors would be possible in future studies with more variables in the
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21 10 dataset including a way to identify those confounders.
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30 13 In conclusion, we have applied a modified novel strategy to measure ‘health gain’
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32 14 associated with an integrated care intervention at a population level. We found that
33
34 15 there were no differences in inpatient payments. Our findings suggest that irrespective of
35
36 16 the ideal principles behind integration, linking multiple health providers to deliver
37
38 17 population based diabetes care is complex and improvements in health outcomes remain
39
40 18 difficult to achieve.
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17
18 11 The views expressed are those of the authors and not necessarily those of the NHS, the
19 12 NIHR or the Department of Health.

20 13 **Contributors**

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23 14 D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods
24 15 and revised the manuscript; Y.C. validated the method and re-analysed the data
25 16 independently; Z.Z. designed the analysis framework and revised manuscript; D.S.
26 17 designed the study, revised the analysis framework, revised the manuscript and
27 18 interpreted the findings.

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35 23 **Competing interests**

36
37
38 24 None declared.

40 25 **Ethics approval**

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43 26 No personal identifiers were released to researchers, and all subsequent analyses were
44 27 conducted on anonymised datasets. The work had approval from the Cambridgeshire
45 28 research ethics committee as part of a wider service evaluation and, as such, was deemed
46 29 not to require personal informed consent.

47 30 **Provenance and peer review**

48
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50 31 Not commissioned; externally peer reviewed.

52 32 **Data sharing statement**

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55 33 No additional data are available.
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3 **1 Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient payment**
4 **2 in people with type 2 diabetes and possible effects of an integrated care on the curve.**

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6 3
7 4 *The differences between the respective areas under the curve are shaded. Health gains for*
8 5 *participants with lower inpatient payment.*
9 6 *Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;*
10 7 *Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;*
11 8 *Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.*
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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)
	Inpatient payment, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

The median (inter-quartile range (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

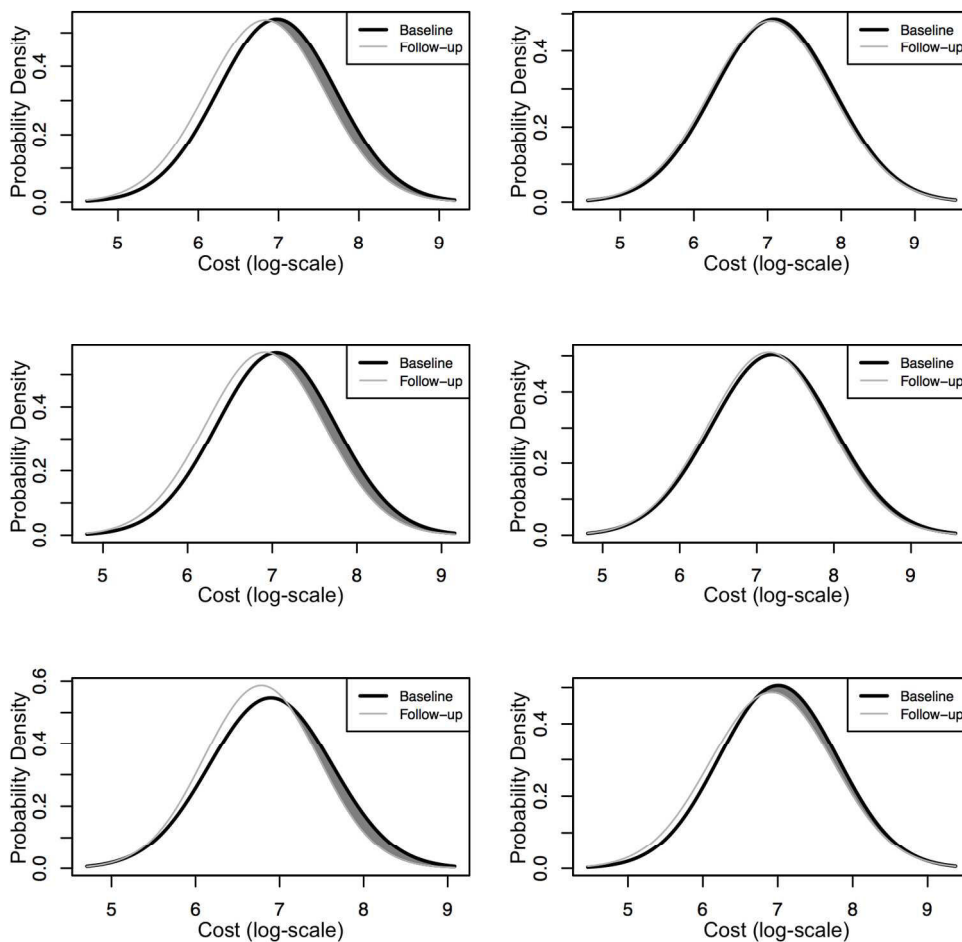
		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	7.69	5.89, 9.74)	0
	≥70 years	2.05	(0.72, 4.13)	0.044796

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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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152x152mm (300 x 300 DPI)



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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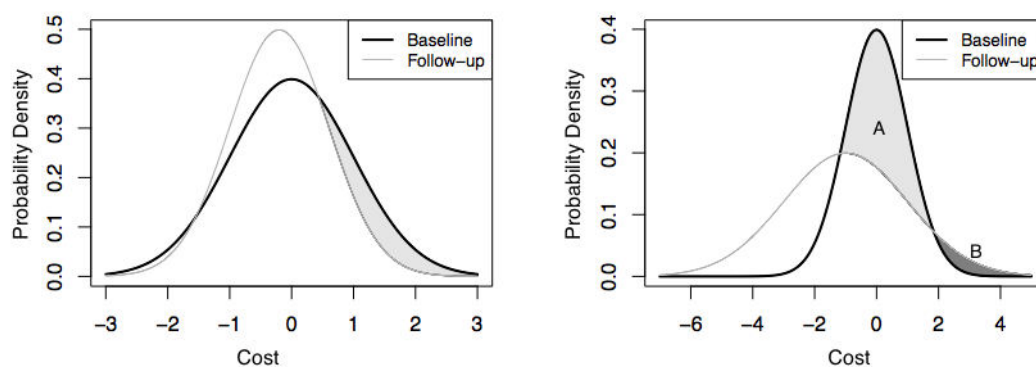
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Online supplemental Technical Appendix

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 $F(\mu_1, \sigma_1, \mu_2, \sigma_2)$. Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as $\text{MIN}(F(\mu_{1min}, \sigma_{1max}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2min}, \sigma_{2max}))$, and $\text{MAX}(F(\mu_{1max}, \sigma_{1min}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2max}, \sigma_{2min}))$.

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.

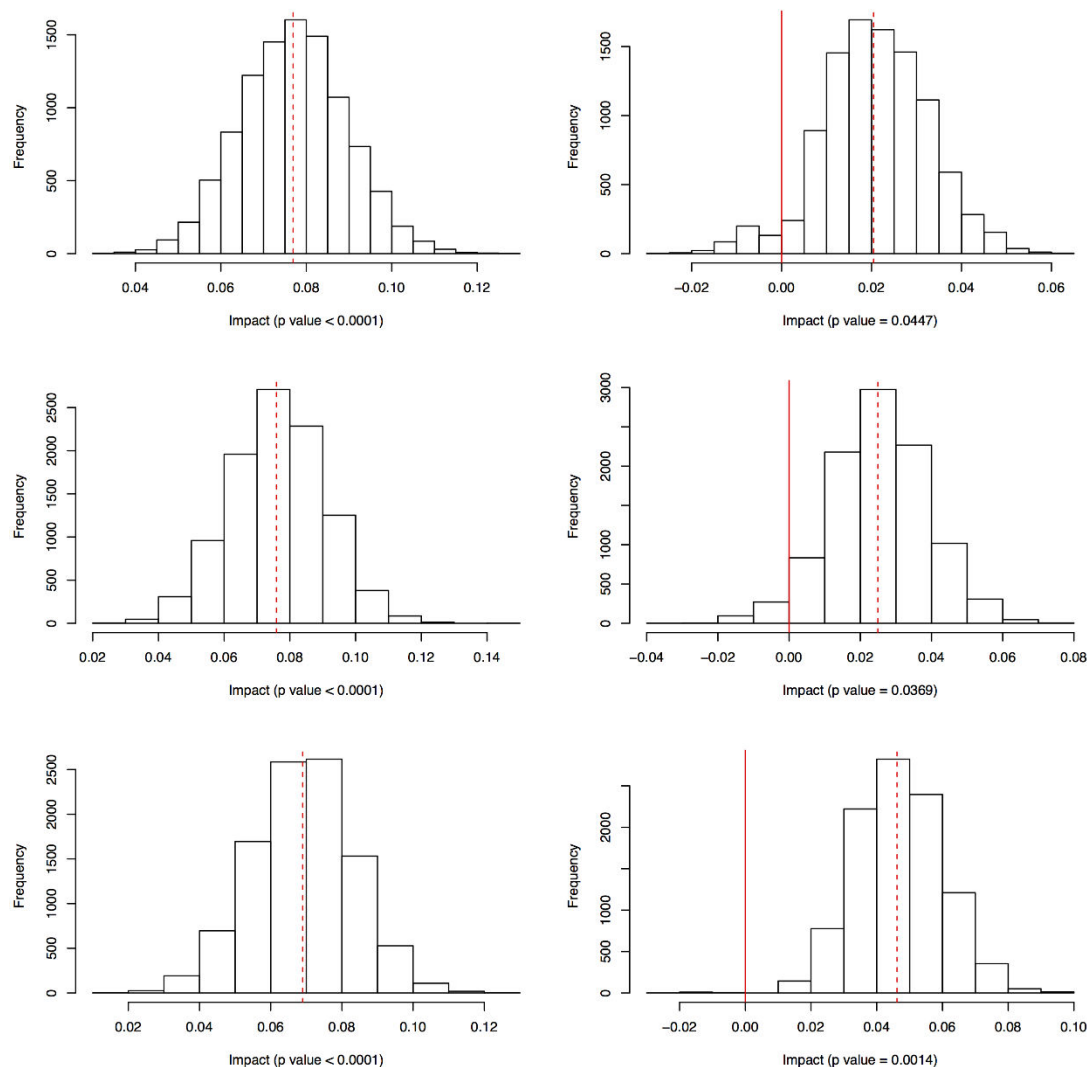
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- (2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear 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.

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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 H_0 : impact ≤ 0 , and alternative hypothesis H_1 : impact > 0 ; $P = [\text{Percentage with impact} \leq 0]$).

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.

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 1

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	<i>Single study-based estimates</i> : Describe fully the design features of the single effectiveness study and why the single	Page 5-6

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 2

		study was a sufficient source of clinical effectiveness data.	
	11b	<i>Synthesis-based estimates</i> : 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	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 3

		applicable, report incremental cost-effectiveness ratios.	
Characterizing uncertainty	20a	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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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Complete List of Authors:	Yu, Dahai; the First Affiliated Hospital, Zhengzhou University, Department of Nephrology; Keele University, Arthritis Research UK Primary Care Centre, Research Institute for Primary Care & Health Sciences Yang, Wei; the First Affiliated Hospital, Zhengzhou University, Department of Nephrology; Washington University in St Louis, School of Medicine cai, yamei; the First Affiliated Hospital, Zhengzhou University, Department of Nephrology Zhao, Zhanzheng; the First Affiliated Hospital, Zhengzhou University, Department of Nephrology Simmons, David; Western Sydney University, Macarthur Clinical School
Primary Subject Heading:	Diabetes and endocrinology
Secondary Subject Heading:	Research methods
Keywords:	intergrated care, Diabetes, Intervention studies, Area under the curve

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Manuscripts

1
2
3 **Title Page**

4 **Title:** Population-level impact of diabetes integrated care on commissioner payments for
5 inpatient care among people with type 2 diabetes in Cambridgeshire: a post-intervention
6 cohort follow up study
7

8
9 **Authors:** Dahai Yu ^{1,2}, Wei Yang ^{1,3}, Yamei Cai ¹, Zhanzheng Zhao ^{1*}, David Simmons
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46 Tables: 3

47 Figures: 1

48 References: 26

49 Online Appendix: 1

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

1
2
3 1 Abstract

4 2 **Objectives**

5 3 Few studies have estimated the effect of diabetes integrated care at a population level.
6 4 We have assessed the impact of introducing a community service led diabetes integrated
7 5 care programme on commissioner payments (tariff) for inpatient care in rural England.

8
9
10 6 **Methods**

11 7 The Diabetes Integrated Care Initiative (DICI) was delivered by a separate enhanced
12 8 community diabetes service, increasing specialist nursing, dietetic, podiatry and medical
13 9 support to primary care and patients, while linking into other diabetes specialist services.
14 10 Commissioner data was provided by the local authority. The difference in area between
15 11 the two overlapping distribution curves of inpatient payments at baseline and follow-up
16 12 (at 3 years) was used to estimate the effect of integrated care on commissioner inpatient
17 13 payments on a population level.

18
19
20 14 **Results**

21 15 Over the three-year period, reduced inpatient payments occurred in 2.7 (1.3 to 5.8) % of
22 16 patients with diabetes aged more than 70 years in the Intervention area. However,
23 17 reduced diabetes inpatient payments occurred in 3.20 (1.77 to 7.20) % of patients aged <70
24 18 years and 4.1 (2.3 to 7.9) % of patients \geq aged more than 70 years in one of the two
25 19 adjacent areas.

26
27 20 **Conclusion**

28
29 21 This enhanced community diabetes services was not associated with substantially
30 22 reduced inpatient payments. Alternative diabetes integrated care approaches (eg with
31 23 direct primary and secondary care collaboration rather than with a community service)
32 24 should be tested.

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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.

1 Introduction

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

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

25 Methods

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2
3 1 East Cambridgeshire and Fenland (ECF: 2009 population 160,000, diabetes population
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5 2 7,790) is largely rural, with a small number of socioeconomically deprived communities
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7 3 [6]. There is no local major hospital (with eg an emergency department), falling within
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9 4 the catchment areas of 4 hospitals outside of the area. Some diabetes outcomes have
10
11 5 been historically poor [11]. A separate, local, diabetes specialist nurse (DSN) led
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13 6 community service was introduced in 2003 [12]. From April 2009, this was replaced with a
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15 7 new Diabetes Integrated Care Initiative (DICI) using additional finance (£250,000 pa), in
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17 8 an attempt to address continuing health disparities [13]. The components of the DICI has
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19 9 been described in the previous publications [14]. The health district includes two other
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21 10 areas, Huntingdonshire and Greater Cambridge, which did not receive the full
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23 11 intermediate team and are able to serve as 'control' areas, although each hospital based
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25 12 service would have continued with its own internal service developments. We have
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27 13 previously reported no impact on metabolic control or hospitalisation rates in spite of full
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29 14 implementation of the service [6].
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33 15 De-identified electronic Secondary Uses Service (SUS) data for across Cambridgeshire
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35 16 were obtained for recorded inpatient tariff between April 2007 (ie 2 years before the DICI
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37 17 contract commenced) and March 2012. Practice, patient age, elective/non elective status,
38
39 18 ICD10 and Health Related Group (HRG) coding were included in the dataset. Diabetes
40
41 19 was considered present if E10-E14 was in any ICD10 field and, as the primary cause of
42
43 20 admission if coded in the first field [15, 16]. Inpatient payments recorded in 2008-2009
44
45 21 were used as baseline, to compare with that recorded in 2011-2012 as the end of the
46
47 22 intervention period. Using the Sarkadi et. al. method, the mean and standard deviation
48
49 23 for normal distributions before and after the intervention can be estimated. The "health
50
51 24 gain" is defined as the area between the two distribution curves on the right side, where
52
53 25 the distribution density after intervention is lower (the shaded area in supplemental **Error!**
54
55 26 **Reference source not found.**Figure 4 left). In our study, 'health gain' represents the

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3 1 proportion of patients with reduced inpatient payments between the baseline and
4
5 2 intervention period. The reduction in commissioner payments reflects reduced needs in
6
7 3 care and thus improvement in health.
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12 5 Sarkadi's method has outlined ways to calculate the impact when the two distributions
13
14 6 have the same standard deviation (SD), or when the follow-up group has smaller mean
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16 7 and smaller SD at the same time. However we have noticed when using real data that the
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18 8 follow-up-group might have smaller mean but larger SD. To accommodate this situation,
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20 9 we have modified the Sarkadi's method as described in online supplemental technical
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22 10 appendix and online supplemental Figure 1. The health gain distributions are presented in
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24 11 online supplemental Figure-2 to illustrate the health gains at a population level.
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31 13 In addition to the Normal distribution originally used in Sakadi's method, three other
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33 14 distributions, Gamma distribution, Log-Normal distribution and Normal distribution of
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35 15 log-transferred payment data were attempted to fit the data. The goodness-of-fit
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37 16 statistics, Akaike information criterion (AIC), Bayesian information criterion (BIC), and log-
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39 17 likelihood were tested over four distributions and the distribution with the minimum AIC,
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41 18 BIC and maximum log-likelihood was chosen as the final distribution to examine the
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43 19 impact.
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49 21 Bootstrapping is used to obtain a p value for the probability of health gain larger than
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51 22 zero. We randomly sampled data points with replacements from the original data
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53 23 separately for the baseline and follow-up, so that we obtain bootstrapped data with the
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55 24 same numbers of data points. These are used to obtain an estimation of the health gain
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1 after perturbation. This process is repeated 1000 times. The probability of observing
2 estimations less than or equal to zero is calculated, and used as the approximation of the
3 p value for testing whether health gain is significantly larger than zero.

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

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

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

14 **Results**

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

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

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2
3 1 Four distribution (Normal distribution, Gamma distribution, Log-Normal distribution and
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5 2 Normal distribution of log-transformed payment data) were attempted to fit the
6
7 3 payment data as presented in Supplemental Table 1. The Normal distribution of log-
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9 4 transformed payment data was chosen to estimate the impact on the intervention for its
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11 5 minimum AIC and BIC and its maximum log-likelihood.

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13
14 6 The magnitude of the intervention at the population level is presented in Table-3.
15
16 7 Significant 'health gain' was observed both in the intervention area and control areas,
17
18 8 especially among patients aged less than 70 years. In the intervention area, East
19
20 9 Cambridge and Fenland, 7.69% (95 Confidence Interval (CI) 5.89-9.74%) and 2.05% (0.72 to
21
22 10 4.13%) of patients aged less than 70 years and aged more than 70 years, respectively had a
23
24 11 reduced inpatient payment, compared with the population in the baseline period. In
25
26 12 Huntingdonshire, the 'health gain' was 6.90% (5.63 to 8.68%) and 4.62% (2.22 to 7.23%)
27
28 13 among patients aged less than 70 years and patients aged more than 70 years,
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30 14 respectively. In Greater Cambridge, the 'health gain' was 7.59% (5.63 to 9.94%) and 2.49%
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32 15 (1.46 to 4.58%) among patients aged less than 70 years and patients aged more than 70
33
34 16 years, respectively.

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38 17 To allow comparisons, the estimated impact, based on a Normal distribution, is presented
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40 18 in Supplemental Table 2. In the intervention area, East Cambridge and Fenland, 2.74%
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42 19 (1.29 to 5.81%) of patients aged more than 70 years had a reduced inpatient payment,
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44 20 compared with the population in the baseline period. In one of the control areas, Greater
45
46 21 Cambridge, 'health gain' was also observed in 3.20 (1.77 to 7.20) % of patients aged less
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48 22 than 70 years and 4.14 (2.27 to 7.86) % patients aged more than 70 years, respectively.
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50 23 Significant 'health gain' was not identified within the population in Huntingdonshire over
51
52 24 the study period.

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1

2 **Discussion**

3

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

16

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

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3 1 or in contexts where multiple primary care organisations work with a single specialist
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5 2 provider under an integrated insurance scheme [6]. The integrated care intervention
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7 3 carried out in ECF followed a nurse led service with one of the goals reducing referrals (ie
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9 4 payments) to hospital outpatients. This philosophy, rather than progressing to truly
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11 5 integrated services carried through the intervention period, albeit as part of a wider
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13 6 programme that included ‘vertical integration’ developments. It was perhaps to be
14
15 7 expected that attempts at creating such greater ‘vertical’ integration in information
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17 8 management, clinical governance, budget and overall management were agreed but not
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19 9 implemented, actions more achievable within a single organization. There was an
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21 10 attempt to create a single equal partner network model [22] nearing the end of the
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23 11 intervention period, but this as not funded by the local commissioners.

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26 12 The failure to implement integrated information management, almost certainly
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28 13 contributed to communication and integration difficulties. Most integrated care
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30 14 initiatives attempt to include data sharing [23] and this was not possible within the local
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32 15 information governance arrangements. This was noticed by the patients and was a
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34 16 source of frustration. Interestingly, integration was perceived as happening when there
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36 17 was one person ‘fronting up’ for all those involved. Case management has been proposed
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38 18 as one approach to integration, and requires the case manager to corral and coordinate
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40 19 the services for a given individual [18].

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44 20 Whether our findings are due to a unique set of circumstances, or expected as part of a 3
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46 21 compartment model (primary care, intermediate care, and secondary care) is unclear, but
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48 22 there are indications that the circumstances are not special. There are calls for more
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50 23 integration and less fragmentation in health care [23], yet the evidence on what works in
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52 24 England is limited [24, 25]. The latest changes in commissioning in the English NHS, with
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54 25 emphasis on the need to consider ‘Any qualified Provider’ in service delivery, and

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3 1 associated market procurement approaches, could well impair the quality of diabetes
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5 2 care while increasing overall cost, if the experience here is reproduced elsewhere.
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7 3 Similarly, as a 'natural experiment', it was not possible to measure the impact of
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9 4 integrated care on inpatient payments at an individual level. Instead, we estimated the
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11 5 proportion of the population showing 'health gain' (reduced inpatient payments) from
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13 6 the integrated care intervention by using the distribution curve of inpatient payment.
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15 7 Although the method was within the conceptual framework proposed by Sakardi, some
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17 8 modifications to the methodology were made to overcome methodological drawbacks,
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19 9 for example requiring the same standard deviation for two Gaussian curves: something
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21 10 unlikely to occur in real scenarios. We believe this revised method would be more
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23 11 applicable to evaluate the 'health gain' for interventions at a population level.
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27 12 There are limitations to our study. This was not a randomised trials, so any changes could
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29 13 be due to secular trends, although we do compare with the two other areas in
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31 14 Cambridgeshire. The data depended on the completeness of the coding of diabetes, and
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33 15 there being no systematic change in coding over this time period. We found that at least
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35 16 one provider had high diabetes ascertainment [10]. Data access restrictions prevented
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37 17 adjustment for some important co-variables. As the data used was record- rather than
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39 18 individual based, repeat inpatient records were unable to be linked, however, the record-
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41 19 based data still provides a range of plausible estimations. Moreover, within a relatively
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43 20 fixed diabetes population served by a local 'closed' inpatient care and tariff system, the
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45 21 likelihood for patients having a second hospital admission, would still be relatively low
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47 22 (although higher than those without diabetes) [10]. In other words, inpatient payments
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49 23 at two time-points are considered completely independent of each other. We
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51 24 acknowledge that this current analysis still yields findings subject to confounding bias
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53 25 unable to be measured in this study. The 'impact' observed in our study may therefore
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3 1 only reflect measured changes in the DICI and ‘control’ regions respectively, rather than
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5 2 due to the DICI itself, as the DICI care model was not randomly assigned. As a result of
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7 3 data access restrictions, it is not possible in this study to identify those with multiple
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9 4 admissions (and payments) that would provide ‘redundant information’. The application
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11 5 of bootstrapping ignoring such redundant information might lead to a mis-application of
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13 6 Sarkadi’s tool and might inadvertently increase the false positive rate: something to be
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15 7 taken into consideration when interpreting the findings in this study. There might be
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17 8 other potential unidentified confounders in this study and evaluation seeking other
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19 9 confounding factors would be possible in future studies with more variables in the
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21 10 dataset including a way to identify those confounders.
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27 12 In conclusion, we have applied a modified novel strategy to measure ‘health gain’
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29 13 associated with an integrated care intervention at a population level. We found that
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31 14 there were no differences in inpatient payments. Our findings suggest that irrespective of
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33 15 the ideal principles behind integration, linking multiple health providers to deliver
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35 16 population based diabetes care is complex and improvements in health outcomes remain
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37 17 difficult to achieve.
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43 19 **References**

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11 6 **Acknowledgements**
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14 7 The views expressed are those of the authors and not necessarily those of the NHS, the
15 8 NIHR or the Department of Health.

16
17 9 **Contributors**
18

19 10 D.Y. analysed the data and drafted the manuscript; W.Y. revised the statistical methods
20 11 and revised the manuscript; Y.C. validated the method and re-analysed the data
21 12 independently; Z.Z. designed the analysis framework and revised manuscript; D.S.
22 13 designed the study, revised the analysis framework, revised the manuscript and
23 14 interpreted the findings.

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31
32 19 **Competing interests**
33

34 20 None declared.

35
36 21 **Ethics approval**
37

38
39 22 No personal identifiers were released to researchers, and all subsequent analyses were
40 23 conducted on anonymised datasets. The work had approval from the Cambridgeshire
41 24 research ethics committee as part of a wider service evaluation and, as such, was deemed
42 25 not to require personal informed consent.

43
44 26 **Provenance and peer review**
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46 27 Not commissioned; externally peer reviewed.

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48 28 **Data sharing statement**
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51 29 No additional data are available.
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3 **1 Figure 1. Using the normal (Gaussian) curve to demonstrate the distribution of inpatient payment**
4 **2 in people with type 2 diabetes and possible effects of an integrated care on the curve.**

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6 3
7 4 *The differences between the respective areas under the curve are shaded. Health gains for*
8 5 *participants with lower inpatient payment.*
9 6 *Left top: East Cambridge and Fenland, <70 years; right top: East Cambridge and Fenland, ≥70 years;*
10 7 *Left middle: Great Cambridge, <70 years; right middle: Great Cambridge, ≥70 years;*
11 8 *Left bottom: Huntingdonshire, <70 years; right bottom: Huntingdonshire, ≥70 years.*
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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)
	Inpatient payment, £	683 (468, 1635)	823 (498, 2475)	677 (502, 1666)	808 (469, 2220)	781 (505, 1688)	1031 (611, 2508)

The median (inter-quartile range (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

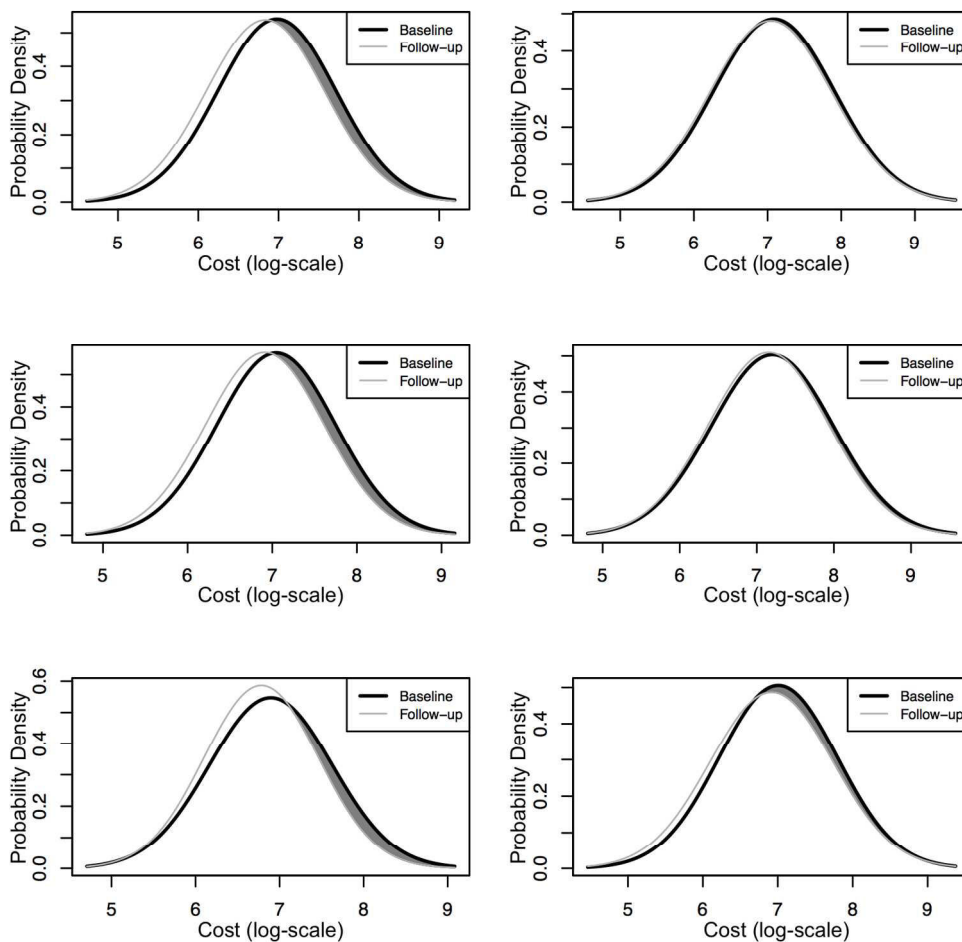
		Impact, %	95% confidence interval, %	P value (bootstrapping)
East Cambridge and Fenland	< 70 years	7.69	5.89, 9.74)	0
	≥70 years	2.05	(0.72, 4.13)	0.044796

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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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152x152mm (300 x 300 DPI)



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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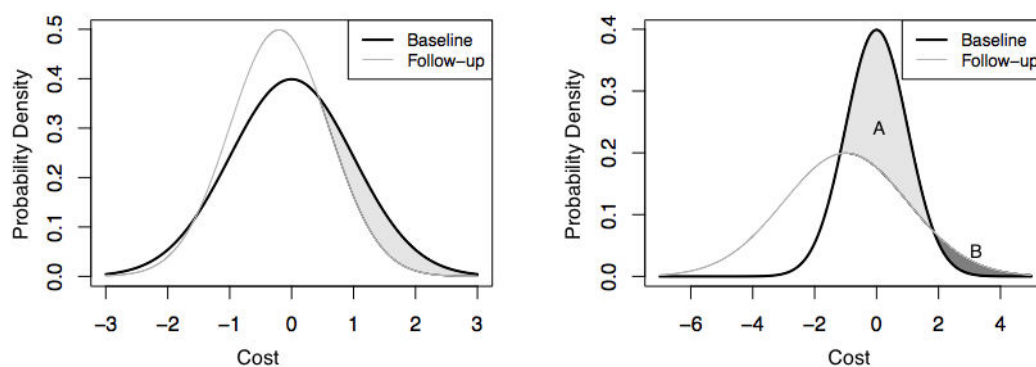
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Online supplemental Technical Appendix

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 $F(\mu_1, \sigma_1, \mu_2, \sigma_2)$. Sarkadi et. al. get the lower and higher bounds of confidence interval for the health gain as $\text{MIN}(F(\mu_{1min}, \sigma_{1max}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2min}, \sigma_{2max}))$, and $\text{MAX}(F(\mu_{1max}, \sigma_{1min}, \mu_2, \sigma_2), F(\mu_1, \sigma_1, \mu_{2max}, \sigma_{2min}))$.

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.

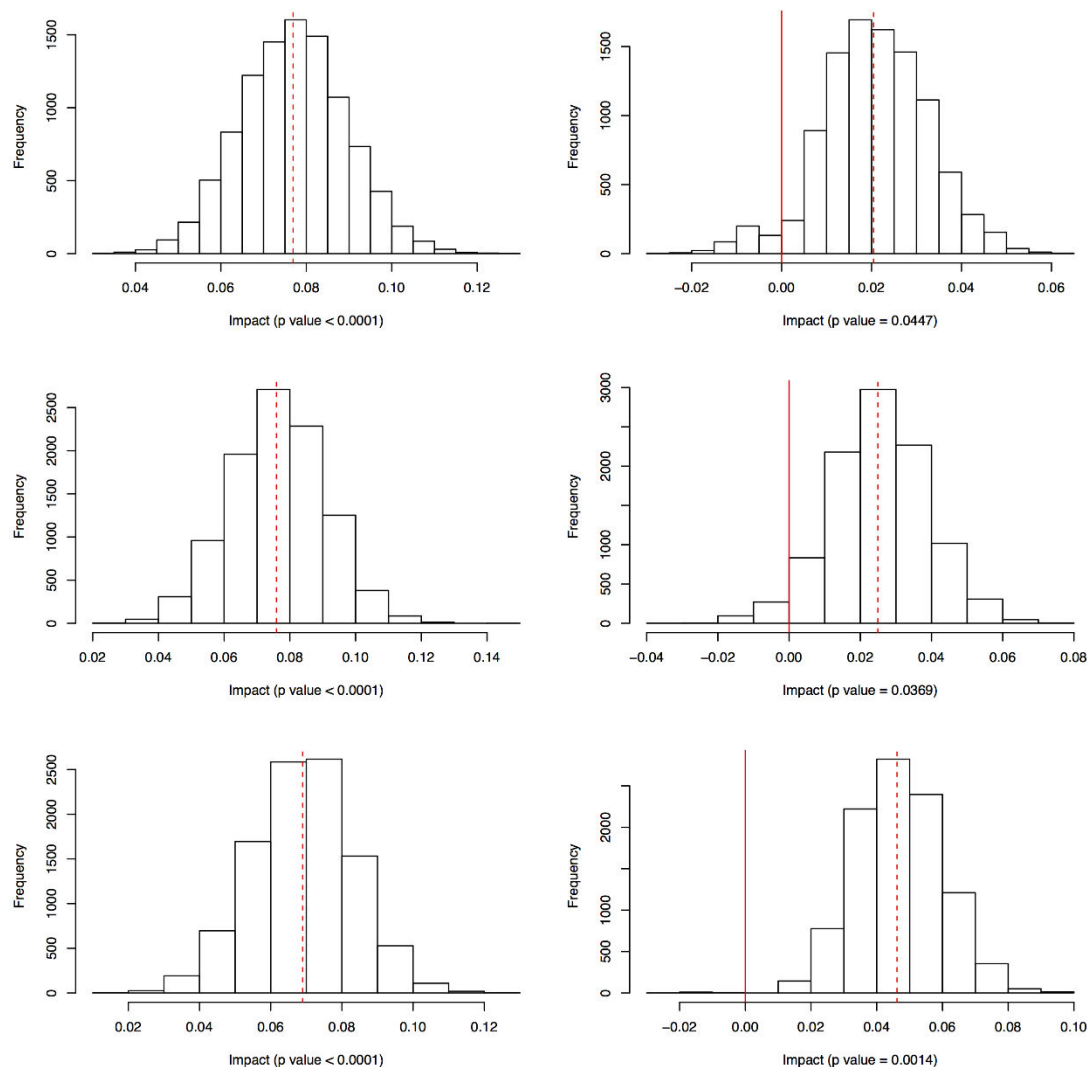
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- (2) However, if the situation is as in the right graph in Supplemental Figure 1, where the density of follow-up is only lower compared to the baseline in the region between the two crossover points, the original method has failed to make a clear 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.

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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 H_0 : impact ≤ 0 , and alternative hypothesis H_1 : impact > 0 ; $P = [\text{Percentage with impact} \leq 0]$).

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.

Consolidated Health Economic Evaluation Reporting Standards – CHEERS Checklist 1

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	<i>Single study-based estimates</i> : Describe fully the design features of the single effectiveness study and why the single	Page 5-6

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		study was a sufficient source of clinical effectiveness data.	
	11b	<i>Synthesis-based estimates</i> : 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	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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

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		applicable, report incremental cost-effectiveness ratios.	
Characterizing uncertainty	20a	<i>Single study-based economic evaluation</i> : 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	<i>Model-based economic evaluation</i> : 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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