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Assessing the impact of heart failure specialist services on patient populations

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Abstract

Background: The assessment of the impact of healthcare interventions may help commissioners of healthcare services to make optimal decisions. This can be particularly the case if the impact assessment relates to specific patient populations and uses timely local data. We examined the potential impact on readmissions and mortality of specialist heart failure services capable of delivering treatments such as b-blockers and Nurse-Led Educational Intervention (N-LEI).

Methods: Statistical modelling of prevented or postponed events among previously hospitalised patients, using estimates of: treatment uptake and contraindications (based on local audit data); treatment effectiveness and intolerance (based on literature); and annual number of hospitalization per patient and annual risk of death (based on routine data).

Results: Optimal treatment uptake among eligible but untreated patients would over one year prevent or postpone 11% of all expected readmissions and 18% of all expected deaths for spironolactone, 13% of all expected readmisisons and 22% of all expected deaths for b-blockers (carvedilol) and 20% of all expected readmissions and an uncertain number of deaths for N-LEI. Optimal combined treatment uptake for all three interventions during one year among all eligible but untreated patients would prevent or postpone 37% of all expected readmissions and a minimum of 36% of all expected deaths.

Conclusion: In a population of previously hospitalised patients with low previous uptake of b-blockers and no uptake of N-LEI, optimal combined uptake of interventions through specialist heart failure services can potentially help prevent or postpone approximately four times as many readmissions and a minimum of twice as many deaths compared with simply optimising uptake of spironolactone (not necessarily requiring specialist services). Examination of the impact of different heart failure interventions can inform rational planning of relevant healthcare services.

Background

Heart failure has a survival rate worse than for many common cancers [1,2] and is responsible for 4% of all UK deaths [3]. Hospital admissions are frequent [4-6], partly preventable [7], and costly [8]. Apart from Angiotensin Converting Enzyme (ACE) inhibitors or Angiotensin 2 (A2) antagonists, medical treatments reducing mortality and readmissions in heart failure due to Left Ventricular Systolic Dysfunction (LVSD) include b-blockers [9], and, in New York Heart Association (NYHA) class III/IV patients, spironolactone [10]. Non-pharmacological "nurse-led" educational intervention (N-LEI) reduces readmissions [11], and may also reduce mortality, particularly long-term [12]. N-LEI consists of multidisciplinary interventions which may include: dietary advice, patient and carer education about heart failure treatment and management, education about recognition of signs of decompensation and suitable action plans, medication review by either a pharmacist or a doctor, exercise training, counselling, and follow-up contacts either at home, or at a specialist clinic, or by telephone [11]. The typical patient receiving N-LEI is one with a recent hospital admission due to heart failure. The number of patient contacts and the intensity of the intervention is greater at the start of the programme (i.e. during the first few weeks) and its overall duration is typically short term (i.e. up to six months, but usually shorter).

Nearly all heart failure patients requiring hospital admission have advanced disease (NYHA class III/IV) [13] and therefore usually require post-discharge introduction and gradual up-titration of b-blockers over an average of four follow-up appointments [14], usually under specialist supervision [15-18]. Delivering N-LEI requires employment of appropriately trained and accredited nursing staff. In practice the provision of both b-blockers and N-LEI depends on the existence of specialist services, usually in the form of a heart failure clinic run by specialist medical and nursing staff [14], which may explain why interventions improving prognosis are sub-optimally used [19].

Evidence-based medicine has greatly contributed to rational decision-making in the treatment of individual patients, but the delivery of interventions to populations of patients is not always based on evidence [20]. Assessing the expected impact of proposed interventions can support the rational planning of healthcare services and inform health economic analysis. Several recent publications have assessed the potential incremental impact of various cardiovascular interventions [21-25], on national [21,22] or hypothetical [23-25], populations, using novel and promising modelling techniques [26]. There is a need to extend healthcare impact assessment to setting-specific patient populations, using timely local data. This may improve the accuracy and practical relevance of the assessment, as local decision makers may prefer calculations that use local population data. We therefore examined the potential impact of increasing uptake of evidence-based interventions on a population of heart failure patients with history of previous hospitalisation in Stockport NHS Trust, a UK district general hospital of Greater Manchester, using local data on outcomes, and treatment uptake and contraindication rates. The study hospital serves a notional reference population of about 300,000 (or about 0.5% of the total UK population). In the study setting, about 85% of all patients with an emergency medical admissions are from Stockport, a population with slightly better health characteristics to the general UK population, with a Standardised Mortality Ratio from all causes (all ages) of 96 (95% CI 94–98)[27]. At the time of the study, the introduction of specialist heart failure services in the local health economy was under consideration.

Methods

Summary of the approach

The impact of the proposed specialist heart failure services was defined as the sum of the impact of three constituent non-invasive effective interventions: spironolactone, b-blockers (in the form of carvedilol) and N-LEI. Carvedilol was chosen because it is one of the two such b-blockers currently licensed for use in heart failure in the UK [28], and the one most commonly used [14]. For heart failure patients with history of previous hospitalisation who were eligible but untreated the potential impact on all cause readmissions and mortality associated with optimal treatment uptake during one year was calculated. The impact of examined treatments on other outcomes, such as quality of life, was not calculated due to lack of appropriate baseline data.

The potential impact of other treatments (e.g. ACE inhibitors or A2 antagonists, and also aspirin and statins for patients with heart failure due to coronary heart disease) was excluded from the calculations, as their delivery is much less dependent on specialist services and because pre-existing high local uptake meant that the potential for incremental improvement was negligible (see Results). Analysis was restricted to heart failure patients with previous hospitalisation because although patients in an early disease stage may also use a heart failure specialist service, they were judged not to represent its primary target.

Basic modelling formula

The annual potential impact of an intervention was calculated using an adaptation of previously described methods [23,24]. The number of prevented or postponed events for treatment *a* (PPE_a) is calculated as:

$$\mathbf{PPE_a = n * P_{e\text{-}u(a)} * r_{e\text{-}u(a)} * RRR_{(a)}}$$

where: n = number of patients with condition of interest, $P_{e\text{-}u(a)}$ = proportion of patients that are eligible but untreated, $r_{e\text{-}u(a)}$ = probability of event (or mean number of events per patient) per eligible but untreated patient during study period, and $RRR_{(a)}$ = relative risk reduction associated with treatment (where RRR(a) = 1 - RR(a)). The potential impact was calculated for one year [23,24].

The proportion of patients that are eligible but untreated ($P_{e\text{-}u}$) equals the proportion of eligible (P_e) minus the proportion of patients already treated (P_t). Treatment eligibility is defined as the absence of contraindication or intolerance, or $P_e = 1 - (P_{ci} + P_{int})$, where P_{ci} denotes the proportion of patients with a contra-indication, and P_{int} the proportion of patients with treatment intolerance [23]. This means that the proportion of patients that can be expected to have either a known contraindication to treatment (e.g. pre-existent renal impairment in relation to spironolactone treatment) or treatment intolerance due to side effects are by definition excluded from the proportion of patients that are "eligible but untreated".

The value of $r_{e\text{-}u(a)}$ is rarely available from observational data sources which usually provide information about event rates (or mean number of events per patient) in the "total" patient population, independently of treatment status (r_{total}). However, when the proportion of treated patients is small or nears zero, using values of r_{total} to approximate $r_{e\text{-}u(a)}$ is reasonable, and this approach was used in this paper. It is acknowledged that it is theoretically possible to calculate the value of $r_{e\text{-}u(a)}$ as a function of r_{total}, if the proportion treated and untreated are known (e.g. from audit): $\mathbf{r_{e\text{-}u(a)} = r_{total} / [P_{u(a)} + (P_{t(a)} * RRR_{(a)})]}$, where $P_{u(a)}$ = proportion untreated and $P_{t(a)}$ = proportion treated and $RRR_{(a)}$ = the relative risk reduction for the treatment *a*. However such a calculation assumes that untreated patients do not include those ineligible due to contraindication or intolerance, and therefore has the potential to introduce error, particularly in the case of relatively small sample sizes.

The value of $n * P_{e\text{-}u}$ represents the target number of "*patients-to-be-treated*", through improvement in the quality of provided care. The value of $n * r_{e\text{-}u}$ represents the number of "*expected events*" among all patients with the condition of interest.

Data sources used in modelling

The annual mean value of *n* was calculated from the study hospital Hospital Episodes Statistics (HES) data for the three financial years period 1998–2001, relating to patients with an emergency medical admission due to heart failure primary diagnosis (ICD code: I50.0–I50.9) discharged alive. We restricted data to patients with heart failure as primary diagnosis (i.e. coded in the first position) as opposed to any secondary diagnoses.

For the proportion of treated patients, and also for the proportion of patients with a treatment contraindication, local audit data (Appendix 1) were applied to the study population. In the absence of local data, for spironolactone and carvedilol respectively, treatment intolerance was taken to represent either the proportion of patients in the treatment arm of RALES [10] who discontinued treatment due to adverse events, or the proportion of patients in the treatment arm of COPERNICUS [29] who withdrew from treatment during the first 8 weeks (Table 1). Clearly there was no pharmacological intolerance related to N-LEI, but P_{int} was used for consistency to denote the proportion of patients declining the intervention. In the absence of such estimate from published studies a value for P_{int} was imputed, based on the assumption that given the non-invasive nature of the intervention it was unlikely to be worse than that reported for the two pharmacological therapies (Table 1).

The r_{total} value for death was derived by data-linking the HES data (on hospitalised patients with heart failure primary diagnosis) with Office for National Statistics mortality data (three financial year average 1998–2001). The r_{total} value for the mean number of all cause readmissions per patient was derived from HES data analysis (three financial years average 1998–2001). As explained, these values were used as approximates for the values of $r_{e\text{-}u}$.

Table 1: "Patients-to-be-treated " by type of treatment, based on proportion of patients with a contraindication and intolerance (*n* = 286)

	Proportion with contra-indication (P_{ci})	Prop. intolerant (P_{int})	Proportion eligible $P_e = 1 - (P_{ci} + P_{int})$	Proportion already treated (P_t)	$P_{e\text{-}u} (= P_e - P_t)$	Incremental number of "patients-to-be-treated" ($= n * P_{e\text{-}u}$)
Spironolactone	0.08* (95% CI 0.04–0.15)	0.08 [10] (95% CI 0.06–0.1)	0.84	0.25* (95% CI 0.18–0.34)	0.59	169
b-blockers	0.2* (95% CI 0.13–0.28)	0.052 [29] (95% CI 3.9–6.5)	0.748	0.12* (95% CI 0.07–0.19)	0.628	180
N-LEI	0*	0.15**	0.85	0	0.85	243

*Estimates from local audit data **Based on informed judgment-see methods

RRR values for all-cause readmissions (from now on: readmissions) and all-cause mortality (from now on: mortality) were obtained from RALES (spironolactone) [10], COPERNICUS (carvedilol) [30,31] and McAlister et al. (N-LEI) [11]. A RRR value for the effect of spironolactone on readmissions was not originally reported, therefore this was estimated from data presented in tables of the original publication [10]. RRR values were assumed to be time-independent and applied to a year-period [23,24]. The effect (RRR) of spironolactone and carvedilol is independent of sex, age and heart failure disease stage [10,30,31] and such independence was assumed for N-LEI based on relevant suggestions in the literature [32,33].

Modelling of patient eligibility for combined treatment

Spironolactone, b-blockers and N-LEI may be used in combination in eligible patients. As for other cardiovascular treatments [21,22,34], an independent cumulative effect of different interventions can be assumed, and the combined relative risk (RRR) calculated as originally proposed by Mant and Hicks [35].

$$(RRR_{a+b}...) = 1 - (RRR_a) * (RRR_b) * ....$$

where a, b ... different interventions, and a+b... combined interventions.

Therefore the expected health impact was calculated in three ways. First for each of the interventions offered in isolation (Model 1). Second, assuming an independent but combined effect for the two pharmacological interventions (Model 2). Third, assuming an independent but combined effect for all three interventions, including N-LEI (Model 3). The latter assumes that the mechanism by which N-LEI reduces readmissions is through life-style modification rather than improvement in compliance with pharmacological therapies such as spironolactone and b-blockers. This is a reasonable assumption in relation to sprionolactone and b-blockers in particular, since the great majority of patients included in reported N-LEI trials did not receive either of these two drugs, due to lack of evidence about the effectiveness of these treatments at the time the studies were performed. For example, less than 10% of patients received b-blockers in the most recently reported N-LEI trial [5].

As spironolactone, b-blockers and N-LEI have different contraindication and intolerance profiles, it was assumed that eligibility for any one intervention is independent of any other. Formulae based on simple probability theory were therefore used to calculate the number of patients who can be expected to be eligible for none, one, two or three interventions (Appendix 2).

Confidence intervals, sensitivity analysis

For all reported proportions exact binomial 95% confidence intervals (CI) were calculated. To examine the robustness of the modelling, and to also simulate the impact of examined interventions in alternative settings, estimates of individual variables used in the modelling were varied sequentially, using data from alternative settings, or, in the absence of empirical data, based on reasonable assumptions.

Results

Among 286 patients (95%CI: 250–320) expected to be discharged alive following a heart failure hospitalisation during one year, the percentage of eligible but untreated patients was 59% for spironolactone, 63% for carvedilol and 85% for N-LEI (Table 1). The crude uptake of aspirin or warfarin, statins and ACE inhibitors or A2 antagonists among audited patients was 73%, 88% and 79% respectively.

Using local data (see Methods), the annual risk of death among all heart failure patients discharged alive (independently of treatment status) was 32% (95%CI: 29–35%) and the annual mean number of readmissions per patient was 0.54 (95% CI: 0.44–0.63).

The respective RRR for readmission and mortality used were 18% (CI impossible to calculate without access to raw data) and 30% (95%CI: 18–40%) for spironolactone [10]; and 20% (CI not reported in original publication, p value = 0.002) [31] and 35% (95%CI: 19–48) [30] for carvedilol. For N-LEI the RRR for readmission was 23% (95%CI: 14–32%), however it was not possible to use a RRR value for the effect on mortality, as no such significant effect is reported in the literature [RRR 0.06 (95% CI: -0.19–0.25)] [11].

Impact on annual mortality and readmissions by individual or combined treatment

Optimal uptake of spironolactone during one year among all eligible but untreated patients would prevent or postpone 16 readmissions and 16 deaths (or 11% of all expected readmissions and 18% of all expected deaths). The corresponding numbers for carvedilol are 19 readmissions and 20 deaths (or 13% of all expected readmisisons and 22% of all expected deaths); and for N-LEI 30 readmissions (or 20% of all expected readmissions) and an uncertain number of deaths (Model 1, Table 2 (see Additional file 1) and Figure 1). Optimal uptake of spironolactone and carvedilol in combination during one year among all eligible but untreated patients would prevent or postpone 34 readmissions and 33 deaths (or 22% of all expected readmissions and 36% of all expected deaths) [Model 2, Table 2 (see Additional file 1)]. Optimal uptake of spironolactone, b-blockers and N-LEI in

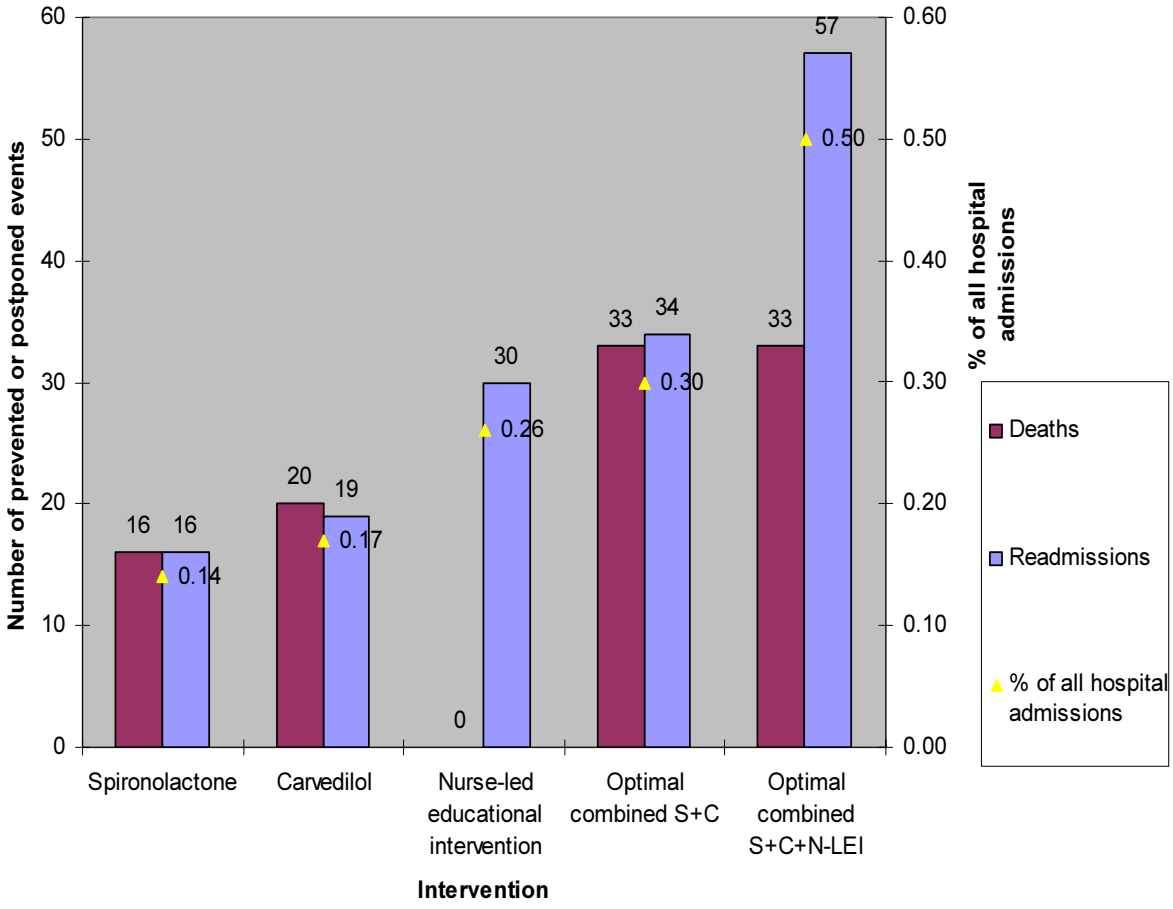

Figure 1
Potential impact of optimal uptake of interventions (S = spironolactone, C = Carvedilol, N-LEI = Nurse-Led Educational Intervention)

combination during one year among all eligible but untreated patients would prevent or postpone 57 hospitalisations and a minimum of 33 deaths (or 37% of all expected readmissions and a minimum of 36% of all expected deaths) [Model 3, Table 2 (see Additional file 1)] -the impact on deaths may be higher as there is uncertainty about a true effect of N-LEI on mortality. Comparatively, spironolactone, carvedilol and N-LEI in combination would prevent or postpone about four times as many readmissions and a minimum of twice as many deaths due to all causes compared to spironolactone therapy alone.

Sensitivity analysis

Optimal uptake of combined treatment with spironolactone, carvedilol and N-LEI during one year among all eligible but untreated patients generally changed little with variation of individual components of the modelling equation, informed by data relating to alternative settings, or, in the absence of such information, on reasonable assumptions (Table 2). The exception was in relation to estimates of readmissions prevented or postponed, due to a large difference between literature-based estimates [5] and those observed in the study setting.

Table 3: Sensitivity analysis estimates of events prevented or postponed by factor, varied sequentially

Varied factor	Original estimate (source)	Varied estimate (source)	New estimate of number of deaths prevented or postponed (% change from previous "best" estimate-33)	New estimate of number of readmissions prevented or postponed (% change from previous "best" estimate-57)
b-blocker uptake	12% (local audit)	34% (ref. [46])	27 (-18%)	53 (-8%)
b-blocker intolerance	5.2% (ref. [29])	29% (ref. [4])	27 (-18%)	52 (-9%)
N-LEI eligibility	85% (informed judgement)	75% (conservative estimate)	33 (0%)	55 (-4%)
Annual risk of death	32% (data-linkage of HES to ONS mortality data)	29% (ref. [47])	30 (-9%)	-
Mean number of readmissions	0.54 (HES data analysis)	1.41 (ref. [5])	-	150 (+280%)
Estimate of number of patients that can benefit from treatment	286 (local hospital statistics data)	358 (assuming 25% of of heart failure patients are not coded with heart failure primary diagnosis)	41 (+25%)	72 (+25%)
RRR of all treatments	As per references [10,11,30,31]	20% reduction in all estimates (assuming that such a reduction in effectiveness might be applicable due to overall reduced baseline risk compared to that reported in original trials)	27 (-19%)	47 (-20%)

HES: Hospital Episodes Statistics; ONS: Office for National Statistics; Ref.: Reference RRR: Relative Risk Reduction

Discussion

Specialist heart failure services offered to patient populations with previous low uptake of b-blockers and no previous uptake of N-LEI can potentially help prevent or postpone approximately four times as many readmissions and at least twice as many deaths compared with optimisation of uptake of interventions not necessarily requiring specialist services such as spironolactone. The seemingly small impact in terms of overall hospital admissions burden should be examined in the context of increasing demand for emergency medical care, and the paucity of evidence on the preventability of medical readmissions in general [36,37]. The findings therefore provide evidence for establishing specialist services for heart failure patients with a history of previous hospitalisation in healthcare settings currently with low uptake of b-blockers and without provision of N-LEI. They also illustrate a method by which accurate and timely local health information could support local decision-making about the introduction of evidence-based interventions.

Although the cost-effectiveness of specialist heart failure services was not examined in this study, impact assessment could inform further economic analysis [24]. While we have not attempted a cost-effectivenes analysis, this would be an important future endeavour. The costs relating to implementing N-LEI, and also prescribing costs, will have to be balanced against the improved health outcomes. The prevalence of heart failure appears to be increasing in the population, and cost estimates associated with its optimal management are important.

At present in the UK there is a lack of population-based data about the uptake of heart failure interventions. However the majority of the UK population is not covered by specialist heart failure services and population treatment uptake of b-blockers and N-LEI in particular is thought to be very low. Therefore, although the present study relates to only one setting, and the study hospital only covers about 0.5% of the total UK population, the findings may currently (2004) be applicable to many other UK settings, and the number of deaths and readmissions that can be prevented or postponed at a national (UK) level may be much greater. A larger study, using data from multiple hospital settings on outcomes, and treatment uptake and contraindication rates, would be desirable. A nationally co-ordinated audit of heart failure care, similar to the one for management of acute myocardial infarct [38] will be helpful, as a means to not only monitor improvement in care but also to inform impact assessment of various treatments and, subsequently, planning of services.

Incremental rather than absolute health benefits relating to interventions were calculated, as in practice, incremental change is most important in decision-making. Estimates of incremental health impact are subject to the variation in current treatment uptake, as both the absolute and relative (i.e. in relation to alternative interventions) health impact of an intervention will vary if the treatment uptake of the same or other interventions change. An example of this notion, in relation to varying levels of b-blocker uptake in different settings, has informed sensitivity analysis. Similarly, in settings already delivering N-LEI the potential incremental impact of this intervention will be smaller.

Locally derived estimates of risk of death and mean number of readmissions per patient usually relate to the survival and readmission experience of all patients, independently of treatment uptake status. Such estimates (i.e.

r_{total}, to approximate r_{e-u}) can still be used to assess the incremental impact of interventions [23], particularly if the proportion of patients previously receiving the intervention(s) of interest is small (e.g. in this study 0% – 25%). As generally untreated patients have a higher probability of death or readmission the resulting values most likely under- rather than over-estimate the calculated expected impact.

Direct empirical evidence about the combined effect of the interventions examined by our study is limited, although reassuringly a similar effect size of spironolactone is reported in the minority (11%) of the RALES participants who also received b-blockers [10]. It is likely that the impact on readmissions of maximizing uptake of spironolactone has been under-estimated by this study, as, without access to the RALES raw data, the RRR value used was not based on "time-to-event" analysis. The assumption that the effect of N-LEI is independent of the effect of spironolactone and b-blockers is reasonable, since the great majority of patients included in reported N-LEI trials did not receive either drug, due to lack of evidence about the effectiveness of these treatments at the time the studies were performed. For example, less than 10% of patients received b-blockers in the most recently reported N-LEI trial [5]. However, more and better empirical evidence about the combined effect of the examined heart failure interventions in the future would be desirable.

The use of hospital statistics data for incidence, survival and health economic studies has a long tradition in heart failure epidemiology [2-4,8,39]. Routine data could potentially both under- and over-estimate the true number of cases, through "sensitivity" and "specificity" coding errors. The audit survey provides confidence in using local routine data, as the "specificity" error was only 7.5%, compared with estimates of about 10% reported in the literature [40]. An overall high level of accuracy for the local HES data is indicated by the lack of any obvious internal validity problems (e.g. lack of any marked variation between years in relation to admission and readmission rates) and the concordance with national data on the proportion of al emergency medical admissions that are due to heart failure [41], and patients' sex distribution, and length of stay. In practice it will be difficult for healthcare managers to be able to use anything other than HES data in their planning considerations. Care should be given when planning services for specific local settings in using activity data relating to periods longer than one-year (e.g. three years), to reduce random variation of activity, as in the current study.

The modelled figure of 286 patients per year relates to heart failure patients that have been discharged alive, having discounted for in-hospital deaths occurring among patients with primary diagnosis of heart failure. In Scotland, during the period 1990–1995, the mean number of admissions independently of discharge status (dead or alive) was 341 in large teaching hospitals and 244 in large general hospitals -possibly of similar type to Stockport NHS Trust [42]. Therefore the number of patients modelled in our study is of the expected order compared to the literature. We have opted to use data relating to patients with "primary" diagnosis of heart failure, as nationally in the UK and in the literature [2,3,8,15,41,42], the use of primary diagnosis is well-established for estimates of heart failure disease burden, and local policy makers will be familiar with such use of the data. We have however addressed the potential for under-estimation of true disease burden, and, subsequently, the potential underestimation of the impact of modelled interventions through sensitivity analysis. It has to be noted that the actual level of activity does not affect the proportional order of the impact associated with each individual intervention and that of treatment combinations.

Calculations assume treatment continuity among eligible patients during one year. In reality it would be impossible to review all heart failure patients with previous hospitalisation in specialist clinics perpetually, and in order to sustain treatment uptake the role of primary (non-specialist) care is crucial. Similarly, heart failure patients without prior hospitalisation (e.g. in early disease stage) may in practice be referred to specialist services and benefit from them. The associated impact of services in relation to this patient population was not calculated. Such an assessment may however be constrained by limited evidence of effectiveness of N-LEI in heart failure patients without prior hospitalisation, and by the difficulty (in the absence of accurate and timely information from population-based registries) of obtaining realistic estimates of annual risk of death and number of expected hospitalisations per patient. It is important to notice that the location of a specialist heart failure service can be either in secondary or primary care.

Calculated impact estimates assume a one-year period for a specific cohort of patients from a point in time. This number is unlikely to remain the same over time due to attrition of the cohort and changes in treatment levels and baseline risk. However, in any given setting, the population of heart failure patients is a dynamic one and is subject to variation in number, and also secular trends in treatment levels and baseline risk of mortality and readmission. Therefore, in subsequent years, new estimates would be required to allow for these changes over time.

We have estimated benefits of treatments in this study exclude the proportion of patient with either a contraindication or treatment intolerance (see Methods, "Basic modelling formula used"). In practice, a patient with a recognised contraindication to a given treatment might adversely be prescribed that treatment, resulting in harm. Similarly, in clinical practice treatment intolerance presupposes exposure to treatment, which might also be harmful. Ideally future healthcare impact assessment studies should attempt calculation of potential harm, as well as expected benefit.

Conclusion

In a population of previously hospitalised patients with low previous uptake of b-blockers and no uptake of N-LEI, optimal combined uptake of interventions through specialist heart failure services can potentially help prevent or postpone approximately four times as many readmissions and at least twice as many deaths compared with simply optimising uptake of spironolactone (not necessarily requiring specialist services). Since the publication of the UK government's coronary heart disease national service framework [43], regular audit of heart failure treatment is an explicit component of clinical governance activities in all NHS hospitals. Routine health data, such as HES and mortality data, are available at the local (NHS Trust and Primary Care Trust) level. Open-access web-based resources, such as *Clinical Evidence* [44], can be easily used to help identify effectiveness estimates from the literature. We suggest that local use of information from audit, routine administrative data and the literature can help estimate the impact of different heart failure interventions and inform rational planning of relevant healthcare services, as it can provide realistic estimates of expected outcomes.

Appendix 1. Audit population and methodology

A routine audit survey of heart failure management in the study hospital conducted by one of the authors (GL) was used as the source of information for uptake of spironolactone and b-blockers; also for information on contraindication rates to spironolactone (i.e. previous clinical diagnosis of renal failure, or creatinine value greater than 200 mg/l) and b-blockers (i.e. chronic obstructive pulmonary disease [COPD], asthma, or heart block worst than first degree). (Under specialist clinical supervision it may be possible to treat some HF patients who also have COPD with b-blockers, however COPD is a well-recognised contraindication to b-blocker therapy [15,28]). The records of ninety-nine per cent (199/202) of all patients with an emergency medical admission due to heart failure primary diagnosis (ICD code: I50.0–I50.9) during January and September 2001 were accessed. For patients with more than one admission during the study period, only the earliest admission was reviewed. The accuracy of clinical coding was verified based on echocardiography or clinical diagnosis by a consultant physician, and cases that were miscoded or inaccurately diagnosed in the first instance were excluded. Patients who according to the European Society of Cardiology guidelines [45] are classified as heart failure without Left Ventricular Systolic Dysfunction (LVSD) (e.g. either atrial fibrillation or heart valve disease with preserved ventricular function) were also excluded. Information was collected by records inspection, including inpatient notes, discharge letters/prescriptions, echocardiography reports, correspondence to general practitioners or other hospital consultants, and follow-up appointment letters or notes. Data collection on echocardiography findings and the prescription of b-blockers, was extended to a six-month period after live discharge. Forty-four (22%) of all inspected cases were excluded: 14 (7.5%) due to miscoding; 16 (8%) due to subsequent echocardiography refuting the clinical diagnosis; 11 (5.5%) due to having heart failure without LVSD; and 3 (1.5%) due to missing data. Among the remaining cases 35 (21.5%) died during the admission episode and 120 patients were discharged alive. The mean age of these patients was 77 years, 40% were male, and 57% had heart failure diagnosis based on echocardiography.

Appendix 2. Calculation of combined treatment eligibility

To calculate the number of patients expected to be eligible for one, two and three treatments in combination: Let there be 3 groups of size A, B, C indicating the number of patients eligible for treatments a, b and c respectively out of a population total T then:

• the number likely to be eligi ble for none of the treatments will be

[(1 - [A/T]) * (1 - [B/T]) * (1 - [C/T])] * T

• the number likely to be eligible for treatment "a" alone will be

[(A/T) * (1 - [B/T]) * (1 - [C/T])] * T

and similarly for treatments "b" and "c"

• the number likely to be eligible for treatments "a" and "b" in combination will be

[(A/T) * (B/T) * (1 - [C/T])] * T

and similarly for treatment pairs "b" and "c", and "a" and "c".

• the number likely to be eligible for treatments "a" and"b" and "c" in combination will be

[(A/T) * (B/T) * (C/T)] * T

giving a total of eight possible groups. A similar approach was used for eligibility to two treatments.

Competing interests
None declared.

Authors' contributions
The study was conceived and designed by GL in collaboration with, and based on previous work, by RFH, RE, PM and GC. GL, DH and GC collected data. GL, DH and PM analysed data. PM is responsible for confidence interval analysis. All authors wrote the article.

Additional material

Additional File 1
Annual expected health impact by individual treatment offered in isolation or by combination of treatments Results of Models 1, 2 and 3, including number and percentages of death and readmissions postponed or prevented.
Click here for file
[http://www.biomedcentral.com/content/supplementary/1472-6963-4-10-S1.doc]

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