The risk of overestimating cost savings from hospital-at-home schemes: A literature review

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ARTICLE INFO

ABSTRACT

Background: The concept of hospital-at-home means that home treatment is provided to patients who would otherwise have been treated in the hospital. This may lead to lower costs, but estimates of savings may be overstated if inpatient hospital costs are priced incorrectly.

Objective: The objective of this study was to evaluate the quality of cost analyses of hospital-at-home studies for acute conditions published from 1996 through 2019 and to present an overview of evidence.

Design: Literature review

Data Sources: The PubMed and NHS EED databases were searched.

Review Methods: The overall quality of studies was evaluated based on Quality of Health Economic Studies (QHES) score, design, sample size, alignment of cost calculation with study perspective, time horizon, use of tariffs or real resource use and clarity of calculations. Furthermore, we systematically assessed whether cost savings were likely to be overestimated, based on criteria about the costing of inpatient hospital days, informal care costs and bias.

Results: We identified 48 studies. The average QHES score was 60 out of a maximum of 100 points. Almost all studies violated one or more criteria for the risk of overestimation of cost savings. The most frequent problems were the use of average unit prices per inpatient day (not taking into account the decreasing intensity of care) and biased designs. Most studies found cost differences in favour of hospital-at-home; the range varied from savings of €8773 to a cost increase of €2316 per patient.

Conclusion: Overall quality of studies was not good, with some exceptions. Many cost savings were probably overestimated.

What is already known about the topic?

- Many studies have found cost savings for hospital-at-home programmes, where care was provided in patients' homes instead of in the hospital.
- There is a risk of overestimating these savings when comparisons are biased, when important cost categories are not included, or when the costs of inpatient hospital days are calculated incorrectly.

What this paper adds

- This review examined the quality and the risk of bias in these studies, in particular with regards to the costs of inpatient hospital days and informal care.
- In general, study quality was not good. Many savings were probably overestimated.

Introduction

The concept of hospital-at-home means that home treatment is provided to patients who would otherwise have been treated in the hospital. The hospital admission may be avoided completely (admission avoidance) or shortened by early assisted discharge. Hospital-at-home can be attractive from different points of view.

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Patients may prefer home treatment to staying in the hospital, they may have a smaller risk of nosocomial infections, beds in the hospital may be used more efficiently and the total costs of care may be lower.

However, there is a risk that cost savings are overestimated in cost(-effectiveness) studies (Jonsson and Lindgren, 1980). Firstly, part of the care of patients is transferred to relatives, friends, neighbours and other informal caregivers, even if patients receive formal professional care at home. The fact that care is delivered outside of the health care system, or even that it is unpaid, does not mean that no costs are involved. From a societal perspective, these informal care costs should not be ignored, as is stated in many international guidelines for economic evaluation studies, which recommend all costs to be included, whoever bears them (Drummond et al., 2015; Zorginstituut Nederland (National Healthcare Institute), 2016).

Secondly, since the reduction of inpatient hospital days is the principal driver of potential cost savings, the calculation of the costs per day is crucial. Not all days are the same. An inpatient hospital day is a combination of inputs rather than a consistent unit of resource use. The intensity of care may be different across diseases, patient groups, and interventions. Standard or reference costs may not be sufficiently representative for the use in a particular study (Tan et al., 2010). Furthermore, even within diseases and diagnoses, the intensity of care during inpatient days is not necessarily constant. It is very plausible that below-average numbers of resources are used for patients who could have been treated outside the hospital (Lilford and Shaw, 1998). For example, co-morbidities or more severe disease can make patients ineligible for hospital-at-home or can make that treatment less attractive to them. These patients would receive more intense care in the hospital than patients without co-morbidities and with less severe disease.

Moreover, since treatment intensity may decrease over the course of an admission, the savings from a reduction of one inpatient day are likely to be lower than the average daily cost (Jonsson and Lindgren, 1980; Drummond et al., 2015). Exchanging lower-intensity days for care at home does not affect the number of higher-intensity (more expensive) hospital days. This is likely to have a larger influence on the cost estimates in early discharge studies than in admission avoidance studies.

Several systematic reviews of hospital-at-home studies that paid attention to costs have been published in recent years (Huntley et al., 2017; Echevarria et al., 2016; Conley et al., 2016; Shepperd et al., 2016; Qaddoura et al., 2015; Zhu et al., 2015; Caplan et al., 2012; Ram et al., 2004; Varney et al., 2014; Shepperd et al., 2009, 2009). However, these discussed only selections of all hospital-at-home studies. They either included only randomized controlled trials, (Echevarria et al., 2016; Shepperd et al., 2016; Shepperd et al., 2009, 2009; Ram et al., 2004; Zhu et al., 2015), or specific treatments or types of hospital-at-home (early assisted discharge or admission avoidance)(Echevarria et al., 2016; Zhu et al., 2015; Ram et al., 2004; Shepperd et al., 2009, 2009; Shepperd et al., 2016; Qaddoura et al., 2015; Varney et al., 2014; Conley et al., 2016). Most importantly, all focused on the effectiveness of the intervention and did not extensively discuss costs and costing methodology.

The current review aimed to cast a wider net in order to comprise all papers on the costs of hospital-at-home for acute conditions published from 1996 through 2018. Cost-minimization studies and cost-consequence studies were included as well as full economic evaluations. Modelling studies, observational studies and pragmatic trials were reviewed as well as randomized controlled trials.

The main objective was to assess the quality of the cost analyses of the hospital-at-home studies, with an emphasis on the method of calculating the costs of inpatient hospital days. The secondary objective was to present an overview of currently available estimates of cost savings of hospital-at-home services. Finally, we investigated what proportions of patients were eligible for the various hospital-at-home programs, since this affects the amount of savings that can be realized.

Methods

Data sources

We used PubMed to search the MEDLINE and PMC databases and we searched the NHS Economic Evaluation Database (NHS EED) for English-language studies published from 1 January 1996 through 31 December 2019. The last search took place on 20 January 2020. Search terms for PubMed were (1) cost, costs or cost-effectiveness and (2) hospital-at-home, early (supported/assisted) discharge, home hospitalization/hospitalization, in-home healthcare or hospital in the home. Search terms for additional studies in NHS EED were 'hospital-at-home' or 'early discharge' or 'early assisted discharge' or 'early supported discharge'. For the exact search terms, see the Appendix. The search terms and selection criteria were developed before the search in order to find all studies of early assisted discharge and admission avoidance as substitution for regular hospital admissions, regardless of the disease area or the study design. The search would also identify review articles, the bibliographies of which were used to identify additional studies.

Study selection

A preliminary selection was made based on titles and abstracts. A second selection round took place after retrieving the full papers. In each round, all studies were screened by two reviewers. Studies had to meet the following criteria:

- a comparison between treatment at home and conventional hospital treatment
- conventional hospital treatment had to include at least one overnight stay and more planned nights in the hospital than the alternative;
- treatment of an acute condition or acute worsening of a chronic disease with a planned treatment period of less than 14 days (no rehabilitation programs);
- costs had to be reported in monetary terms;
- hospital-at-home scheme had to include formal care at home, in the form of visits by nurses, paramedics and/or physicians;
- interventions involving child birth/neonatology and mental healthcare were excluded.

Assessment of quality

Overall methodological quality

The overall methodological quality of each study was independently assessed by two reviewers using the Quality of Health Economic Studies instrument (QHES). This method uses the answers to 16 yes-no questions to express the overall quality of each study in one score on a 0 to 100 scale, with a higher score indicating a better quality (Chiou et al., 2003). Final scores were calculated as the average of the two reviewers' total scores, expressed as a percentage of the potential maximum score on the applicable questions.

Additional elements of the overall assessment were the study design, sample size, the time horizon, the study perspective, the use of tariffs (the amount of money that is actually paid, regardless of the value of the resources) or societally valued resource use (regardless of amount of money that was actually paid), and

the clarity of cost calculations. For non-randomized studies, we assessed whether statistical adjustments were performed to account for possible differences between treatment groups. Clarity was considered sufficient if the studies made clear how resource use, unit prices and total costs were collected and calculated. A perspective was labelled 'societal' when the study aimed to take into account all costs inside the healthcare sector and outside of it, whoever bore them. These might include productivity losses, travel costs and informal care costs. A perspective was labelled 'healthcare' when only costs incurred within the healthcare sector were taken into account. Studies with these perspectives should value resource use in terms of their actual values, since tariffs (or charges or payments to healthcare providers) may not reflect the real costs. Under a payer perspective, costs should be expressed as tariffs or payments.

Assessment of risk of over- or under-estimation of cost savings

Additionally, we performed an analysis of the risk of overestimation of cost-savings. The framework for this assessment was largely based on the publications by Jonsson and Lindgren (1980), Drummond et al. (2015), and Lilford and Shaw (1998), as discussed in the Introduction. It consisted of the following criteria to assess whether a study was likely to have over-estimated costs savings of hospital-at-home programmes.

The first criterion was the use of generic cost prices for inpatient days based on all patients in a hospital, instead of ward- or disease-specific costs. As an extension to this point, we also assessed whether the estimates took into account that eligible patient groups required less intensive care than the average patient with a similar diagnosis or within the same ward. This was not used as a criterion to decide whether overestimation of savings was suspected, however, because it was not always clear that it was relevant.

The second criterion was whether inpatient hospital days over the course of an admission were assumed to be equally costly (average costing) or that the avoided days were analysed separately (day-specific costing).

The third criterion issue was the exclusion of (time) costs of informal care. In addition, we assessed whether the hospital-at-home treatments required the availability of an informal caregiver.

The fourth criterion was a lack of efforts to reduce bias resulting from dissimilarities between the conventionally and experimentally treated samples. Bias may be present when a specifically defined patient group in hospital-at-home was compared to a generic patient group in conventional hospital care; patients self-selected into hospital-at-home and comparator groups; or patients were selected by professionals into hospital-at-home and comparator groups based on medical considerations.

A study was considered having a high risk of overestimating savings if the first criterion – average instead of disease specific inpatient unit costs – was not met or if the fourth criterion – pro-hospital-at-home biases – was not sufficiently addressed. The second criterion - average instead of day-specific costing was a criterion for early assisted discharge studies only, because it is likely that the least costly inpatient days at the end of an admission would be replaced by hospital-at-home. the third criterion - ex inclusion of informal care costs – was a criterion for studies from a societal perspective only.

We also acknowledged one study characteristic that could have led to a risk of underestimating the long-term cost savings of hospital-at-home. It is possible that hospital-at-home programmes were provided by a newly set-up organisation, which did not operate at its full potential during the study period. If the full costs of this organisation were allocated to the patients in the study, this could be an overestimate of the longer-term costs per patient and led to an underestimate of the cost savings.

Cost differences and eligible patients

Estimated cost differences were extracted for each study. In order to facilitate comparisons, all cost savings and cost increases were adjusting to the price-level of 2018 using the relevant national consumer price indices and then converted into euros at purchasing power parity (PPP) for the average price level of the Eurozone in that year (Organisation for Economic Co-operation and Development (OECD), 2019).

If reported, we included the proportion of patients who would be eligible for hospital-at-home treatment, based on the numbers of assessed patients for inclusion in the study.

Results

Search results

The search resulted in a total of 831 potentially eligible papers. After inspection of the abstracts, 113 remained. Examination of the full text led to the exclusion of 63 papers. Two studies were presented in two papers (Caplan et al., 1998; Jester and Hicks, 2003b, 2003a; Board and Caplan, 2000). This means that the 50 papers that were finally included, contained 48 studies. Reasons for excluding initially selected articles are presented in Table 1. Two studies were presented as a small-scale pilot study or an introductory demonstration of cost-effectiveness analysis (Levine et al., 2018; Jester and Hicks, 2003a).

Assessment of overall methodological quality

QHES scores

The results of the overall quality assessment are presented in Table 2. The average QHES score was 60. Almost a third of the papers scored less than half of the potential 100 points. The highest scores were by attained by Echevarria et al. (2018), Shepperd et al. (1998), Hernandez et al. (2003) and Kameshwar et al. (2016): 93, 91, 90 and 89, respectively.

Four of the QHES items were not addressed appropriately by more than half of the studies: explicitness about the costing perspective; the use of statistics or sensitivity analysis to describe uncertainty around the results; appropriateness and clarity of cost calculations; and the acknowledgment and discussion of potential biases.

Design

About half of the studies, 26 out of 48, were randomized controlled trials (RCT); 21 were non-randomised (observational) studies. The remaining study was based on decision models, in which information from several sources was combined mathematically.

One of the RCTs still introduced bias by including in their analysis only patients who were treated at home successfully (Vianello et al., 2013). It excluded a substantial number of costly treatment failures, while retaining all patients who received the conventional hospital treatment.

Three of the non-randomised studies were designed as sequential controlled trials (Caplan et al., 1998; Leff et al., 2005; Frick et al., 2009). They prospectively followed control group patients before the introduction of a hospital-at-home program and recruited intervention group patients after the start of the hospital-at-home service. Three other studies used historical controls (Kameshwar et al., 2016; Hardy et al., 2001; Smith et al., 2002). They selected the control group retrospectively, while following the intervention group prospectively.

Six studies did not include a control group. Instead, they assumed that the duration of conventional hospital treatment and hospital-at-home treatment would be equal and that there would not be any other cost differences besides the different costs per

Table 1
Search results.

	Search result	**Excluded**	Comparison not right	No formal care at home	No cost analysis	Paediatrics/ obstetrics	Long-term care	Mental health	Language	Review	Study protocol	Double report	**Remaining**
First selection round (after reading abstracts)			**Reasons for exclusion**										
Source													
Pubmed	**730**	**639**	381	396	348	76	40	6	36	68	17	0	**91**
NHS EED	**44**	**42**	21	30	12	5	3	0	0	10	0	0	**2**
Reviews	**57**	**37**	10	4	25	1	1	0	1	0	0	0	**20**
Total	**831**	**718**	412	430	385	82	44	6	37	78	17	0	**113**
Second selection round (after reading full texts)													
Source													
Pubmed		**53**	20	6	11	4	16	0	0	1	0	2	**38**
NHS EED		**1**	1	1	0	0	0	0	0	0	0	0	**1**
Reviews		**11**	3	0	2	1	4	0	1	0	0	0	**9**
Total		**65**	24	7	13	5	20	0	1	1	0	2	**8**

Table 2

Overall methodological quality.

First author	Year of publication	QHES	Design	Statistical adjustments lacking*	Sample size	Cost calculation clear*	Time horizon	Perspective	Cost calculations based on tariffs*
Chronic obstructive pulmonary disease, exacerbation									
Skwarska(Skwarska et al., 2000)	2000	75	RCT	na	122, 62		8 weeks	HC	
Nicholson(Nicholson et al., 2001)	2001	58	RCT	na	13, 12	x	Intervention	HC	x
Hernandez(Hernandez et al., 2003)	2003	90	RCT	na	121, 101	x	8 weeks	Payer	x
Puig-Junoy(Puig-Junoy et al., 2007)	2007	81	RCT	na	103, 77	x	8 weeks	Payer	x
Aimonino(Aimonino Ricauda et al., 2008)	2008	65	RCT	na	52, 52		Intervention	HC	
Goossens(Goossens et al., 2013)	2013	**	RCT	na	70, 69	x	3 months	Soc, HC	
Echevarria(Echevarria et al., 2018)	2018	93	RCT	na	60, 58	x	3 months	HC	
Samaranayake (Samaranayake et al., 2019)	2019	9	Obs	x	136, 123		Intervention	HC	
Joint replacement surgery									
Hensher(Hensher et al., 1996)	1996	63	Obs	x	42,10; 61, 6	x	Intervention	HC	
Jester(Jester and Hicks, 2003b, 2003a)	2003	49	Obs	x	64,45	x	Intervention	HC	
Sigurdsson(Sigurdsson et al., 2008)	2008	82	RCT	na	27, 23	x	6 months	Soc	
Coronary bypass surgery									
Penque(Penque et al., 1999)	1999	68	RCT	na	25, 25		3 months	?	
Booth(Booth et al., 2004)	2004	79	RCT	na	65, 32		12 weeks	HC	
Cancer surgery									
Bonnema(Bonnema et al., 1998)	1998	85	RCT	na	36, 39	x	4 months	Soc	
Evans(Evans et al., 2000)	2000	46	Mod	na	–		60 days	HC	x
Pajaron(Pajaron-Guerrero et al., 2017)	2017	27	Obs	x	50, 63		30 days	HC	
General surgery									
Caplan(Caplan et al., 1998; Board and Caplan, 2000)	1998	51	Obs	x	44, 58; 57,65	x	Intervention	HC	
Fleming(Fleming et al., 2000)	2000	33	Obs	x	37, -		Intervention	HC	
Congestive heart failure									
Patel(Patel et al., 2008)	2008	84	RCT	na	13, 18	x	12 months	HC	x
Mendoza(Mendoza et al., 2009)	2009	79	RCT	na	37, 34	x	12 months	HC	x
Deep venous thrombosis									
Ting(Ting et al., 1998)	1998	22	Obs	x	100, -		Intervention	HC	
Smith(Smith et al., 2002)	2002	38	Obs		28, 28		Intervention	HC	x
Yu (Yu and Sunderland, 2019)	2019	47	Obs	x	64, 64		Intervention	HC	
Diabetes									
Wong(Wong et al., 2005)	2005	5	RCT	na	52, 49	x	Intervention	?	x

Table 2 (*Continued*).

First author	Year of publication	QHES	Design	Statistical adjustments lacking*	Sample size	Cost calculation clear*	Time horizon	Perspective	Cost calculations based on tariffs*
Intravenous antibiotic therapy									
Wolter(Wolter et al., 1997)	1997	61	RCT	na	13, 18		Intervention	HC	x
Steinmetz(Steinmetz et al., 2001)	2001	18	Obs	x	284, -		Intervention	HC	
Wolter(Wolter et al., 2004)	2004	71	RCT	na	44, 38		Intervention	HC	x
Richards(Richards et al., 2005)	2005	49	RCT	na	24, 25		Intervention	Payer	x
Hendricks(Hendricks et al., 2011)	2011	74	RCT	na	35, 57		Intervention	Soc, HC, Payer	
Theocharis(Theocharis et al., 2012)	2012	33	Obs	x	91, -		Intervention	HC	
Rodriguez(Rodriguez-Cerrillo et al., 2013)	2013	21	Obs	x	34, 19		Intervention	HC	
Vianello(Vianello et al., 2013)	2013	60	RCT	na	26, 27	x	Intervention	HC	
Kameshwar(Kameshwar et al., 2016)	2013	89	Obs		124, 204		Intervention		
Teh(Teh et al., 2017)	2017	50	Obs	x	25, 27		Intervention	HC	
Gonzalez(Gonzalez-Ramallo et al., 2017)	2017	36	Obs	x	1324, -	x	Intervention	HC	
Acute care for elderly patients									
Coast(Coast et al., 1998)	1998	62	RCT	na	158, 78	x	3 months	HC	
Jones(Jones et al., 1999)	1999	86	RCT	na	102, 97	x	3 months	HC	
Board(Board et al., 2000)	2000	58	RCT	na	50, 47	x	Intervention	HC	
Hardy(Hardy et al., 2001)	2001	35	Obs	x	149, -	x	Intervention	HC	
Campbell(Campbell et al., 2001)	2001	75	Mod	na	30, 21	x	3 months	HC	
Harris(Harris et al., 2005)	2005	63	RCT	na	143, 142	x	30 days	HC	
Leff(Leff et al., 2005)	2005	74	Obs	x	169, 286		8 weeks	Payer	?
Cryer(Cryer et al., 2012)	2012	0	Obs	x	323, 1048		Intervention	?	x
Levine(Levine et al., 2018)	2018	73	RCT	na	9, 11		30 days	HC	
Levine (Levine et al., 2019)	2019	93	RCT	na	43, 48		30 days	HC	
Tsiachristas(Tsiachristas et al., 2019)	2019	76	Obs		1737, 13,139; 1463, 3994; 433, 1844		6 months	HC	
Various interventions									
Shepperd(Shepperd et al., 1998)	1998	91	RCT	na	15, 17; 35, 49; 45, 39; 108,122; 50,44	x	3 months	HC	
Frick(Frick et al., 2009)	2009	74	Obs	x	48, 92; 54, 89; 37, 71; 30, 34		8 weeks	Payer	?

Abbreviations. HC: healthcare perspective; na: not applicable, randomised study; Obs: observational (non-randomised) study; QHES: Quality of Health Economic Studies score; RCT: randomised controlled trial; Soc: societal perspective. ?: unclear.

* An 'x' denotes that statistical adjustments were lacking, that cost calculations were clear or that tariffs were used.

** This study was not given a QHES score because two of its main authors also wrote this review.

treatment day (Teh et al., 2017; Gonzalez-Ramallo et al., 2017; Steinmetz et al., 2001; Theocharis et al., 2012; Fleming et al., 2000; Ting et al., 1998).

Six quasi-experimental studies recruited a parallel control group. Hensher et al. selected control patients from outside of the catchment area of the hospitals that participated in their hospital-at-home programme (Hensher et al., 1996). Cryer et al. did not report how they selected control patients (Cryer et al., 2012). Four studies, however, assembled a control group that was systematically different from their intervention group. Pajarón-Guerrero et al. compared patients in a hospital-at-home programme for colorectal surgery to patients who did not meet the (social and clinical) criteria for early discharge (Pajaron-Guerrero et al., 2017). Rodríguez-Cerillo et al., Campbell et al. and Jester let patients self-select into intervention or control groups (Rodriguez-Cerrillo et al., 2013; Jester and Hicks, 2003a; Campbell et al., 2001).

Of all non-randomised studies, only four applied at least some statistical adjustments to address potential confounding bias in the estimates of cost differences. Kameshwar et al. and Tsiachristas et al. went furthest by correcting their estimates for age, sex, nature and number of comorbidities and medical history, among other factors. Smith et al., matched control patients 1-to-1 based on age, gender and level of comorbidity. Yu et al. only matched patients based on age and gender. Nine non-randomised studies explicitly applied the same eligibility criteria for intervention and control patients (Leff et al., 2005; Frick et al., 2009; Hensher et al., 1996; Smith et al., 2002; Hardy et al., 2001; Jester and Hicks, 2003a; Kameshwar et al., 2016; Yu and Sunderland, 2019; Tsiachristas et al., 2019).

Several authors reported that the clinical baseline characteristics of the treatment and control groups were similar, but without providing a justification for the selection of baseline characteristics they presented (Frick et al., 2009; Cryer et al., 2012; Hardy et al., 2001; Leff et al., 2005; Rodriguez-Cerrillo et al., 2013; Caplan et al., 1998; Board and Caplan, 2000).

Sample size

Overall, sample sizes were small. The median number of participants was 101 and a quarter of less than 57 for both groups combined. Three studies included more than 1000 patients.

Time horizon

In 25 studies, the follow-up period ended after the initial treatment period, which may not always be sufficiently long to capture all relevant costs and cost differences. These included all studies of intravenous antibiotic therapy and deep venous thrombosis.

Perspective and valuation of resource use

Three quarters of all papers estimated the costs from a healthcare perspective, although most of these did not specify this explicitly. Seven of them incorrectly used tariffs instead of societal valuations of resource use (Evans et al., 2000; Nicholson et al., 2001; Patel et al., 2008; Mendoza et al., 2009; Smith et al., 2002; Wolter et al., 2004, 1997). Four studies (also) took a societal perspective (Goossens et al., 2013; Sigurdsson et al., 2008; Hendricks et al., 2011; Bonnema et al., 1998) and used societal valuations, while all six studies with a payer perspective applied tariffs. For three studies, the perspective could not be inferred from the text (Wong et al., 2005; Cryer et al., 2012; Penque et al., 1999).

Clear cost calculation

More than half of the studies did not give sufficient information about their cost calculations. Especially studies in intravenous antibiotic therapy and deep venous thrombosis were unclear about this, whereas studies in chronic obstructive respiratory disease (COPD), congestive heart failure and elderly patients were generally transparent.

Risk of over- or under-estimating savings

Generic or disease-specific inpatient hospital costs

For most papers it could be established whether generic or disease-specific inpatient hospital costs were used, sometimes even when cost calculations were considered unclear. The great majority, 38 studies, met the criterion of using disease-specific inpatient hospital costs (see Table 3). Four studies used generic cost prices for inpatient days (Mendoza et al., 2009; Steinmetz et al., 2001; Cryer et al., 2012; Wong et al., 2005), while it was unclear for six other papers

(Booth et al., 2004; Patel et al., 2008; Kameshwar et al., 2016; Penque et al., 1999; Rodriguez-Cerrillo et al., 2013; Tsiachristas et al., 2019).

Four studies attempted to adjust inpatient hospital costs for the disease severity of their sample (Goossens et al., 2013; Caplan et al., 1998; Sigurdsson et al., 2008). Caplan et al. and Goossens et al. investigated the amount of time spent by nurses and other healthcare professionals on their particular patient groups during inpatient days. Shepperd et al. used 'dependency scores' to adjust more generic cost estimates for the circumstances of the patient group. Sigurdsson et al. recorded complications at the patient during the admission.

In sensitivity analyses Shepperd et al. and Goossens et al. found much higher hospital costs – and thus savings due to hospital-at-home - if generic cost prices per inpatient day were used, instead of costs that were adjusted for the health status of their specific patient groups.

Average or day-specific inpatient hospital costs

For all but three studies, it could be established whether they used average or day-specific costs for inpatient hospital days. Only three early-assisted discharge studies used day-specific cost prices (Sigurdsson et al., 2008; Goossens et al., 2013; Caplan et al., 1998). For two of the studies with average costing, using a fixed tariff per day was justified by their payer perspective (Puig-Junoy et al., 2007; Hernandez et al., 2003). None of the admission avoidance studies used day-specific costing.

Coast et al. performed sensitivity analyses, in which they assumed lower costs for the last days of admissions and found this had a strong impact on estimated savings (Coast et al., 1998).

Informal care

In 21 studies the availability of an informal caregiver was an inclusion criterion for participation in the hospital-at-home programme. Of the four studies with a societal perspective on costs, only Bonnema et al. and Goossens et al. included the costs of informal care in their calculations (Bonnema et al., 1998; Goossens et al., 2013). Hendricks et al. recorded informal care time, but did not express this in monetary terms (Hendricks et al., 2011). Sigurdsson et al. did not include informal care in their calculations (Sigurdsson et al., 2008).

Biased designs

Twelve study designs were biased towards cost savings from hospital-at-home. Six studies had no control group, but compared results for hospital-at-home with a generic patient (Steinmetz et al., 2001; Gonzalez-Ramallo et al., 2017; Teh et al., 2017; Theocharis et al., 2012; Fleming et al., 2000; Ting et al., 1998). In three other studies, control groups were different from the intervention groups, as a consequence of the selection of patients (Pajaron-Guerrero et al., 2017; Rodriguez-Cerrillo et al., 2013; Jester and Hicks, 2003a, 2003b). Several other non-randomised studies did not adjust for differences between treatment groups, but there it is less clear whether this contributed to an overestimation of cost savings. A tenth study introduced bias by excluding patients

Table 3
Assessment of risk of overestimating cost savings.

First author	Year of publication	Type	Non-disease-specific hospital costs*	Costs not specific for eligible patients*	Average costs per inpatient day*	Availability of informal caregiver required*	Informal care costs not included*	Probable bias in design*	Risk of savings being over-estimated*
Chronic obstructive pulmonary disease, exacerbation									
Skwarska	2000	AA		x	x		x		
Nicholson	2001	AA		x	x		x		
Hernandez	2003	Both		x	x	x	x		x
Puig-Junoy	2007	Both		x	x	x	x		x
Aimonino	2008	AA		x	x	x	x		
Goossens	2013	EAD					x		
Echevarria	2018	Both		x	x				x
Samaranayake	2019	Both		x	x		x	x	x
Joint replacement surgery									
Hensher	1996	EAD		x	x		x		x
Jester	2003	EAD		x	x	x	x	x	x
Sigurdsson	2008	EAD					x		x
Coronary bypass surgery									
Penque	1999	EAD	?	x	?	x	x		?
Booth	2004	EAD	?	x	x		x		x
Cancer surgery									
Bonnema	1998	EAD		x	x	x			x
Evans	2000	Both		x	x		x		x
Pajaron	2017	EAD		x	x	x	x	x	x
General surgery									
Caplan	1998	EAD					x		
Fleming	2000	AA		x	x	x	x	x	x
Congestive heart failure									
Patel	2008	Both	?	x	x		x		x
Mendoza	2009	AA	x	x	x	x	x		x
Yu	2019	Both		x	x			x	X
Deep venous thrombosis									
Ting	1998	EAD		x	x	x	x	x	x
Smith	2002	AA		x	x	x			
Diabetes									
Wong	2005	EAD	x	x	x		x		x
Intravenous antibiotic therapy									
Wolter	1997	EAD		x	x		x		x
Steinmetz	2001	AA	x	x	x		x	x	x
Wolter	2004	EAD		x	x	x	x		x
Richards	2005	AA		x	?	x	x		
Hendricks	2011	EAD		x	x		x		x
Theocharis	2012	AA		x	x	x	x	x	x
Rodriguez	2013	AA	?	x	?	x	x	x	x
Vianello	2013	AA		x	x	x	x	x	x
Kameshwar	2013	Both	?	x	x		x		x
Teh	2017	EAD		x	x		x	x	x
Gonzalez	2017	EAD		x	x	x	x	x	x
Acute care for elderly patients									
Coast	1998	EAD		x	x	x	x		x
Jones	1999	AA		x	x		x		
Board	2000	AA		x	x	x	x		
Hardy	2001	EAD		x	x		x		x
Campbell	2001	Both		x	x		x		x
Harris	2005	Both		x	x	x	x		x
Leff	2005	AA		x	x		x		
Cryer	2012	AA	x	x	x		x		x
Levine	2018	AA					x		
Levine	2019	AA					x		
Tsiachristas	2019	AA	?	?	?		x		?
Various interventions									
Shepperd	1998	Both			x		x		x
Frick	2009	AA		x	x		x		

Abbreviations: AA, admission avoidance; EAD: early assisted discharge; Both: AA and EAD; ?: unclear.
* An 'x' denotes that non-disease-specific hospital were used, that costs were not specific for eligible patients, that average costs per inpatient day were used, that the availability of an informal caregiver was require, that informal care costs were not included, that there was a probable bias in the study design or that there was a risk of savings being overestimated.

who were randomised into the hospital-at-home group if their treatment was not successful (Vianello et al., 2013).

Risk of overestimation of hospital-at-home programme costs

For six studies, specific hospital-at-home service organisation structures were established. Hensher et al. and Jones et al. suggest that more patients might have been treated at home without allocating more resources to their services (Hensher et al., 1996; Jones et al., 1999). Specialized teams were also established for the studies by Hardy et al. and Campbell et al., but they did not mention the risk of slack (Hardy et al., 2001; Campbell et al., 2001). Board et al. write that they have minimized this risk (Board et al., 2000). Caplan et al. conclude that 'real-life savings are likely to be greater' than their study estimates, because they expect home visits to occur at a lower rate outside the study (Caplan et al., 1998; Board and Caplan, 2000).

In all other studies the costing of hospital-at-home was based primarily on the time spent on care by healthcare workers.

Risk of over- or underestimation of cost savings

Based on the criteria described above, 34 of the studies were suspected of having overestimated cost savings or underestimated cost increases for hospital-at-home compared to regular hospital care. These include almost all early assisted discharge studies, which based their calculations on average costs per inpatient day, and most intravenous antibiotic therapy studies, which were likely to be biased in the comparison of treatment groups. Three studies provided insufficient information to assess the criteria, while nine studies met all criteria.

If the stricter criterion of eligible-patient-specific costs had been used, almost all studies would have been considered at risk for overestimation of cost savings. The same goes for the criterion of informal care costs in studies that were not conducted from a societal perspective, but nevertheless required the cooperation of informal caregivers.

Estimated cost differences

Including sensitivity analyses, 71 comparisons of hospital-at-home to regular hospital treatment were made in the 48 studies. Most comparisons, 58 out of 71, showed cost savings for hospital-at-home (see Table 5). The largest savings were estimated by Vianello et al. for neuromuscular disease patients with respiratory tract infection in Italy: €9695, after excluding costly treatment failures in the intervention arm (Vianello et al., 2013). On the other extreme, Harris et al. found cost increases of €2316 for a scheme for elderly patients in New Zealand, which they attributed to the fact that the programme operated at less than full capacity (Harris et al., 2005). In four studies that found cost increases, hospital-at-home patients had a longer treatment duration than hospital patients (Shepperd et al., 1998; Kameshwar et al., 2016; Harris et al., 2005; Hensher et al., 1996). Yu et al. presented only average costs per day of admission, not for the total treatment period (Yu and Sunderland, 2019). Tsiachristas et al. and Levine et al. calculated cost savings as a proportion of the costs of conventional treatment, not in absolute amounts (Tsiachristas et al., 2019; Levine et al., 2018, 2019).

Statistical analyses of differences in costs were hardly performed and confidence intervals around the differences were rarely presented.

Proportion of recruited patients

Twenty-one studies presented the proportions of patients who were found eligible to be admitted to hospital-at-home, or provided information with which these proportions could be calculated (see Table 4). The average proportion was less than half of

Table 4
Proportion of assessed patients eligible for hospital-at-home treatment.

First author	Year of publication	Proportion eligible
Chronic obstructive pulmonary disease, exacerbation		
Skwarska	2000	29%
Nicholson	2001	15%
Hernandez	2003	39%
Puig-Junoy	2007	39%
Aimonino	2008	34%
Goossens	2013	24%
Echevarria	2018	76%
Cancer surgery		
Bonnema	1998	94%
Evans	2000	90%
Pajaron	2017	44%
Congestive heart failure		
Patel	2008	13%
Deep venous thrombosis		
Smith	2002	62%
Intravenous antibiotic therapy		
Wolter	2004	64%
Richards	2005	27%
Acute care for elderly patients		
Coast	1998	80%
Hardy	2001	46%
Harris	2005	47%
Leff	2005	25%
Levine	2018	70%
Levine	2019	56%
Various interventions		
Shepperd,	1998	
hip replacement		20%
knee replacement		25%
hysterectomy		35%

patients. Proportions varied between 15% and 76% for exacerbations of chronic obstructive pulmonary disease; between 44% and 94% after cancer surgery; and from 25% to 80% in programmes for elderly patients. The smallest proportion, 13%, was found in the study by Patel et al. on congestive heart failure (Patel et al., 2008).

Discussion

Summary of findings

There can be many reasons to provide healthcare in patients' homes instead of in the hospital. One of the justifications for the implementation of hospital-at-home services is the expectation of substantial cost savings. Our review has shown that the results as reported by most studies appear to support this, but the quality of this evidence leaves much to be desired. Almost all studies applied calculations, unit costs or research designs that were biased towards larger cost savings for hospital-at-home. This leads to the conclusion that, while most studies found that hospital-at-home was cost-saving, many savings were probably overestimated.

Using a stricter criterion for costing, even more studies would have been considered as probably overestimating cost savings. We settled for the use of disease-specific unit costs as a criterion, although even these are often not tailored to the specific group of patients in the hospital-at-home program. Most severely ill patients – who need the most intensive care - are often not eligible for the programmes. This is consistent with the limited proportions of patients that could be included in many studies.

Furthermore, many studies took a healthcare perspective, but assumed or required the contribution of informal caregivers to the hospitalisation at home. Obviously, excluding informal care costs is correct when the healthcare perspective is adopted. This is why we did not use this criterion for the assessment of risk of overestimation in these studies. Nevertheless, this perspective does not paint

Table 5
Estimated cost savings*.

First author		Year of costing	Perspective	Savings in euros (indexed to 2018)	Savings in euros (not indexed)	Disease/Intervention/Patient group
Chronic obstructive pulmonary disease, exacerbation						
Skwarska	UK	2000	HC	1305	1058	
Nicholson	Australia	2001	HC	1436	1184	
Hernandez	Spain	2000	Payer	1289	908	
Puig-Junoy	Spain	2000	Payer	1342	946	Average cost savings
	Spain	2000	Payer	1072	755	Patients with average disease severity
	Spain	2000	Payer	759	535	Patients with mild COPD
	Spain	2000	Payer	1284	905	Patients with moderate COPD
	Spain	2000	Payer	2351	1657	Patients with severe COPD
Aimonino	Italy	2005	HC	219	173	
Goossens	NL	2009	HC	176	157	
	NL	2009	Soc	−920	−825	
Echevarria	UK	2015	HC	1076	1108	
Samaranayake	Australia	2018	HC	1934	1934	
Joint replacement surgery						
Hensher	UK	1996	HC	−1212	−954	Hip (programme 1)
	UK	1996	HC	−1131	−891	Hip (programme 2)
Jester	UK	2003	HC	939	808	Hip/knee
Sigurdsson	Iceland	2008	HC	2326	2032	Hip
	Iceland	2008	Soc	3112	2718	Hip
Coronary bypass surgery						
Penque	USA	1999	HC	−293	−235	
Booth	UK	2004	HC	356	313	
Cancer surgery						
Bonnema	NL	1994	Soc	3336	2277	Lumpectomy or mastectomy
Evans	Canada	1995	HC	2456	2044	Lumpectomy
	Canada	1995	HC	2312	1924	Mastectomy
Pajaron	Spain	2014	HC	5546	5358	Colorectal surgery
General surgery						
Caplan	Australia	1996	HC	205	163	Herrniorrhaphy
	Australia	1996	HC	227	181	Cholystectomy
Fleming	Australia	1998	HC	833	659	Cholystectomy
Congestive heart failure						
Patel	Sweden	2005	HC	2388	2248	Initial episode
	Sweden	2005	HC	2192	2063	Follow-up (12 months)
Mendoza	Spain	2006	HC	2678	2202	Initial episode
	Spain	2006	HC	1631	1341	Follow-up (12 months)
Yu	Australia	2016	HC	364**	357**	
Deep venous thrombosis						
Ting	Australia	1997	HC	1058	832	
Smith	Australia	2002	HC	1211	979	
Diabetes						
Wong	Hongkong	2003	HC	1860	1716	Glycaemic control programme
Intravenous antibiotic therapy						
Wolter	Australia	1993	HC	2391	1726	Cystic fibrosis exacerbation
Steinmetz	Israel	1999	HC	759	716	Various bacterial and viral infections
Wolter	Australia	?	HC	2414	2072	Various bacterial infections
Richards	NZ	2003	Payer	270	229	Pneumonia
Hendricks	USA	2008	HC	1950	1865	Fever and neutropenia
	USA	2008	Payer	4523	4324	Fever and neutropenia
Theocharis	Greece	2010	HC	0	0	Various bacterial infections
Rodriguez	Spain	2012	HC	1629	1524	Diverticulitis
Vianello	Italy	2010	HC	9596	8562	Respiratory tract infection
Kameshwar	Australia	2013	?	−373	−353	Lower-limb cellulitis
Teh	Australia	2014	HC	1547	1489	Neutropenic fever
Gonzalez	Spain	2013	HC	6278	5991	Various bacterial infections
Acute care for elderly patients						
Coast	UK	1996	HC	1218	991	
Jones	UK	1996	HC	316	257	
Board	Australia	1996	HC	1721	1372	
Hardy	UK	1999	HC	1149	941	
Campbell	UK	1999	HC	2769	2269	
Harris	NZ	1997	HC	−2258	−1818	
	NZ	1997	HC	−129	−104	
Leff	USA	2002	Payer	2421	2044	
Cryer	USA	2010	?		19%	
Levine	USA	2016	HC		67%***	
Levine	USA	2017	HC		25%***	
Tsiachristas	UK	2015	HC		18%***	Site 1
	UK	2015	HC		0%***	Site 2
	UK	2015	HC		−15%***	Site 3
	UK	2015	HC		24%***	Site 1, patients with dementia
	UK	2015	HC		24%***	Site 2, patients with dementia
	UK	2015	HC		13%***	Site 3, patients with dementia

Table 5 (*Continued*).

First author		Year of costing	Perspective	Savings in euros (indexed to 2018)	Savings in euros (not indexed)	Disease/Intervention/Patient group
Various interventions						
Shepperd	UK	1998	HC	−1834	−1506	COPD exacerbation
	UK	1998	HC	−140	−115	Knee replacement
	UK	1998	HC	−155	−127	Hip replacement
	UK	1998	HC	−150	−123	Hysterectomy surgery
	UK	1998	HC	−513	−421	Acute care for elderly patients
Frick	USA	2009	Payer	2368	1999	COPD exacerbation
	USA	2009	Payer	3303	2789	Congestive heart failure
	USA	2009	Payer	3112	2628	Cellulitis
	USA	2009	Payer	1629	1375	Pneumonia

Abbreviations: COPD: chronic obstructive pulmonary disease; HC, healthcare perspective; HK, Hong Kong; NL, Netherlands; NZ, New Zealand; Soc; societal perspective; UK, United Kingdom; USA, United States.

* Negative amounts indicate cost increases.

** Amounts per day of admission.

*** Proportional savings.

a complete picture, since part of the work is transferred out of the health care system.

In some studies in our review, hospital-at-home was associated with cost increases (Hensher et al., 1996; Harris et al., 2005; Goossens et al., 2013; Shepperd et al., 1998; Penque et al., 1999; Kameshwar et al., 2016). This was partly caused by the fact that patients in the regular care group were discharged earlier than patients in the hospital-at-home group. The threshold for adding another day may have been lower in hospital-at-home – or the pressure to discharge a patient could be higher in the hospital.

Implications

It would be helpful if future studies paid explicit attention to the costs of inpatient hospital days and the resources used in providing them. They should try to estimate these costs more specifically for their context and add sensitivity analyses. This is especially important if the implementation of a hospital-at-home scheme is primarily driven by the desire of achieving cost savings. Furthermore, decision makers should contemplate whether they would want to implement hospital at home if cost savings were modest or non-existent. If the answer is yes – hospital-at-home can obviously have other advantages - they should take into account the possibility that projected cost savings are not realised.

We could not calculate the extent of the bias for individual studies or for the list as a whole. However, alternative or sensitivity analysis in the studies by Coast et al., Shepperd et al., and Goossens et al. showed that using different unit prices for inpatient hospital days can be the difference between estimated cost savings and estimated cost increases (Coast et al., 1998; Goossens et al., 2013; Shepperd et al., 1998). Tsiachristas et al. compared unadjusted analyses with analyses that adjusted for several patient characteristics. They found that these adjustments greatly reduced the estimate of savings or even turned them into estimates of cost increases (Tsiachristas et al., 2019).

Ultimately, healthcare costs are determined by the amount of resources that are used and the price per unit. If there are no difference in effectiveness, differences in costs between hospital-at-home and regular hospitalization can attributed to three cost categories: hotel costs, medical and para-medical personnel costs, and organisation costs. Hospital-at-home reduces or eliminates hotel costs, which includes bed costs, heating, cleaning etcetera. It could reduce personnel costs if less care is provided to patients – fewer visits by physicians or less attention from nurses, for instance – or if care is provided by lower paid staff. However, these changes might also be achieved within the hospital. On the other hand, hospital-at-home could increase these costs if the same or more care is delivered, and travel time increases. From a staffing perspective, hospital-at-home can be an inefficient way of providing care because of time lost to travel. Finally, hospital-at-home may require extra coordination costs for the home treatment service. The balance of these three cost categories may be positive, negative or neutral.

Possibility of underestimating cost savings

Our findings do not rule out that some cost savings may have been underestimated. This could be the case when the capacity of the hospital-at-home services was not fully used during a trial. More efficient use could reduce the costs per patient, but only if the overhead costs of a programme form a large proportion of the total costs, or if nurses and physicians in the program were idle while waiting for patients. The vast majority of studies, however, counted time spent per patient instead of fixed programme costs, which essentially restricts this capacity issue to the overhead costs (e.g. staff managing the hospital-at-home service) which needs to be appropriately allocated to the number of patients using the service.

There is also a theoretical possibility that an unadjusted comparison of a hospital-at-home cohort with an inpatient control cohort leads to an underestimation of cost savings. This would happen when disease severity (or intensity of care) would be greater in the hospital-at-home group, for example when they were discharged to a hospital-at-home program because they were sicker and needed post-discharge care. However, we consider this only a theoretical possibility, because many hospital-at-home programmes considered the most severely ill patients ineligible, which made these groups less severely ill, on average, than a generic control group.

Theoretically, it is conceivable that hospital-at-home for one group of patients could lead to cost savings another group. As a consequence of freeing up hospital resources, these different patients could be treated earlier or more intensely, leading to better or quicker recovery and fewer adverse effects. This could potentially save costs. It is definitely possible that resources could be put to a better use elsewhere. However, that question is different from the question of how many resources are saved in patients who are eligible for hospital-at-home.

Nevertheless, it is theoretically conceivable that during experiments, control patients could have been treated more intensely than usual during experiments. This more intense treatment might have shortened admissions for some patients, leading to lower costs than during conventional hospital admissions. If that is the case, cost savings would be underestimated. This reasoning

requires some strong assumptions: that conventional hospital care was not optimal for this group, that hospitals were willing and able to deliver more care to these patients during the experiment, and that patients could actually benefit to such an extent that they recovered more quickly and could be dismissed earlier.

Small sample sizes or short time horizons could obscure potential differences in costs, especially with regards to readmissions. This could be a source of overestimation as well as underestimation of cost savings. In addition, the relevance of readmissions varies per disease or intervention. Better care during the initial episode could lead to cost savings in the somewhat longer term. For instance, a review by Caplan et al. on a different selection of papers found that patients in hospital-at-home programs were less likely, on average, to be re-admitted to the hospital than patients who were treated conventionally (Caplan et al., 2012). However, in most studies in our review that had a sufficiently long follow-up period, re-admission rates were not lower for the intervention group and substantial differences in costs during follow-up were very rare.

Limitations

The most important limitation of this study is the inherent subjectivity in quality assessments. We did our best to reduce this by involving all authors in this process and by formulating explicit and objective criteria where this was possible. The least objective point of assessment was probably the clarity of cost calculations. A second limitation is that we cannot rule out that searching more databases would have led to finding more papers.

Conclusion

In conclusion, our review of the impact of hospital-at-home services on costs has shown that the quality of the evidence is not strong. While most studies report that hospital-at-home was cost-saving compared to inpatient-hospital care, many of these savings were probably overestimated. Overestimation commonly results from 1) the inclusion of less severe patients in the intervention group than in the control group, 2) the use of high unit costs for a day in hospital, which results from averaging costs over patients with different disease severity or over all days of the hospital admission, and 3) the exclusion of the costs of informal care.

Declaration of Competing Interest

The authors report no conflicts of interest. The study was not externally funded.

Acknowledgement

Appendix

The following query was used to search the PubMed database:
("costs and cost analysis"[MeSH Terms] AND "hospital at home"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "early discharge"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "supported discharge"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "assisted discharge"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "home hospitalisation"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "home hospitalization"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "in-home healthcare"[Title/Abstract] AND "hospital"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "hospital at home"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "early discharge"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "supported discharge"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "assisted discharge"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "home hospitalisation"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "home hospitalization"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "in-home healthcare"[Title/Abstract] AND "hospital"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "hospital at home"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "early discharge"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "supported discharge"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "assisted discharge"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "home hospitalisation"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "home hospitalization"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "in-home healthcare"[Title/Abstract] AND "hospital"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "hospital-in-the-home"[Title/Abstract]) OR ("costs and cost analysis"[MeSH Terms] AND "hospital in the home"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "hospital-in-the-home"[Title/Abstract]) OR ("costs"[Title/Abstract] AND "hospital-in-the-home"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "hospital in the home"[Title/Abstract]) OR ("cost"[Title/Abstract] AND "hospital in the home"[Title/Abstract])

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