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Geriatric fracture centre vs usual care after proximal femur fracture in older patients: what are the benefits? Results of a large international prospective multicentre study

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ABSTRACT

Objective The aim of this study was to determine the effect of treatment in geriatric fracture centres (GFC) on the incidence of major adverse events (MAEs) in patients with hip fractures compared with usual care centres (UCC). Secondary objectives included hospital-workflow and mobility-related outcomes.

Design Cohort study recruiting patients between June 2015 and January 2017. Follow-up was 1 year.

Setting International (six countries, three continents) multicentre study.

Participants 281 patients aged ≥70 with operatively treated proximal femur fractures.

Interventions Treatment in UCCs (n=139) or GFCs (n=142), that is, interdisciplinary treatment including regular geriatric consultation and daily physiotherapy.

Outcome measures Primary outcome was occurrence of prespecified MAEs, including delirium. Secondary outcomes included any other adverse events, time to surgery, time in acute ward, 1-year mortality, mobility, and quality of life.

Results Patients treated in GFCs (n=142) had a mean age of 81.9 (SD, 6.6) years versus 83.9 (SD 6.9) years in patients (n=139) treated in UCCs (p=0.013) and a higher mean Charlson Comorbidity Index of 2.0 (SD, 2.1) versus 1.2 (SD, 1.5) in UCCs (p=0.001). More patients in GFCs (28.2%) experienced an MAE during the first year after surgery compared with UCCs (7.9%) with an OR of 4.56 (95% CI 2.23 to 9.34, p<0.001). Analysing individual MAEs, this was significant for pneumonia (GFC: 9.2%; UCC: 2.9%; OR, 3.40 (95% CI 1.08 to 10.70), p=0.027) and delirium (GFC: 11.3%; UCC: 2.2%, OR, 5.76 (95% CI 1.64 to 20.23), p=0.002).

Conclusions Contrary to our study hypothesis, the rate of MAEs was higher in GFCs than in UCCs. Delirium was revealed as a main contributor. Most likely, this was based on improved detection rather than a truly elevated incidence, which we interpret as positive effect of geriatric comanagement.

Strengths and limitations of this study

- ► International multicentre approach (12 hospitals in 6 countries on 3 continents).
- ► Centre allocation and treatment algorithms according to standard care provide 'real world' environment and enhance generalisability.
- ► Not all baseline parameters equally distributed in treatment groups.
- ► Missing data present a challenge for research in this age group.
- ► Issues based on missing data and uneven distribution of baseline data addressed with multivariable analyses including mixed-effects models and sensitivity analyses.

Trial registration number ClinicalTrials.gov: NCT02297581.

INTRODUCTION

Background

The number of older trauma patients is continually increasing worldwide due to increased life expectancies. Age and comorbidities present difficulties beyond fracture care. Perioperative complications, functional decline, increased dependence on support, mortality and high healthcare costs are some of the challenges.[1 2]

Interdisciplinary care, 'geriatric co-management' or 'geriatric fracture centres' (GFCs) have been implemented to improve outcomes. In addition to the involvement of a geriatrician, they use standardised protocols and pathways to optimise treatment. Organisational aspects, for example, reducing the time to surgery and targeting

comorbidities, medication, and nutritional aspects are addressed through an interdisciplinary effort.[3–5] The aim of these measures is to reduce complications, readmissions and mortality, facilitate the return to prefracture mobility status, contribute to secondary fracture prevention, improve patient and family satisfaction, and to provide best value of care to the health system.[6] However, the evidence of benefits of GFCs is still inconclusive.[7–10] Only four randomised studies have been published,[11–14] and no international multicentre trials exist so far.

Objectives

The primary objective of our study was to determine the effect on the incidence of predefined major adverse events (MAEs) in patients with hip fractures, that is, proximal femur fractures, treated in GFCs compared with usual care centres (UCC). Our hypothesis was that less MAEs would occur in GFCs. The secondary objectives included assessments of perioperative information, mortality, mobility status, quality of life, and cost-effectiveness.[15]

METHODS

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Study design and eligibility criteria

The study protocol[15] was approved by the Ethics committees/institutional review boards (IRBs) of all participating centres.

A summary of the most important items is provided below.

This prospective multicentre cohort study was conducted in a GFC and a UCC in each of the following countries: Austria, Spain, the USA, the Netherlands, Thailand, and Singapore. To qualify as GFC, centres needed to have a predefined treatment path for older trauma patients, that provided a fast track in the emergency department, facilitated daily communication among involved specialists, ensured regular visits of a geriatrician preoperatively and postoperatively, and supported daily physiotherapy and access to social workers; UCCs followed their usual procedures, not involving all of these features as a standard.[15] The procedure of site selection has been described elsewhere.[16]

To ensure consecutive enrolment, every potentially eligible patient was asked about their interest in participation at the study site. Main inclusion criteria were an age of 70 years or older and an operatively treated proximal femur fracture. Written informed consent was obtained from all patients or their surrogates prior to enrolment, which took place between June 2015 and January 2017. All patients were treated per standard of local care.

Data collection and outcome measures

Data collected[15] included age, sex, race, smoking status, employment status, comorbidities (Charlson Comorbidity Index, CCI),[17] previous falls and fragility fractures,[18 19] mobility, injury and treatment details, peri-operative information, adverse events (AEs), date of death, and quality of life (EQ-5D and EQ-VAS). Information about death was entered in the case report forms, where reasons for missed visits had to be documented. Source data were verified during onsite monitoring visits. Various other recovery-related parameters[15] will be the subjects of separate publications. Data were captured preoperatively, at discharge from acute care, at discharge to the definitive residential status, at 12 weeks and 1 year after surgery. All source data were entered by site staff into the electronic data capture system REDCap (Vanderbilt University, V. 6.5.2).[20]

The primary outcome measure was the 1-year incidence of the prespecified MAEs delirium, congestive heart failure, myocardial infarction, pneumonia, deep venous thrombosis, pulmonary embolism, and pressure ulcers.[15] Diagnosis of these MAEs was performed according to current standards, following unequivocal diagnostic criteria defined in the study protocol.[15 21–23] On suspicion of delirium, the Confusion Assessment Method (CAM) was used for diagnosis.[24] The CAM includes a cognitive assessment, which we performed by applying the Mini Mental State Examination.[25]

The secondary outcome measures included any other AEs, perioperative information such as the time from admission to surgery, the length of stay in acute care, 1-year mortality, ambulation-focused mobility determined with the Parker Mobility Score (PMS),[26] and the timed up and go (TUG) test.[27 28] Quality of life was measured with the EQ-5D and EQ-VAS.[29 30]

Statistics

Sample size

The sample size was calculated based on the expected difference in the risk to experience 1 of the prespecified MAEs, for which a wide variation has been reported. Depending on the type of complication, incidences range from 4% to 57% in GFCs and from 61% to 71% in UCCs.[8 10 12 31 32] Assuming that 1 year after surgery, the risk to experience at least 1 of the prespecified MAEs was 35% in the GFC group and 55% in the UCC group, an equal sample size of 106 patients per group (212 in total) would be needed to provide a power of 80% with a significance level of 5%. Adjusting for an expected loss of 20% of patients, the required sample size was determined to be 266 (133 per group).

Analysis populations

All analyses were performed on the full analysis population, that is, all enrolled patients.

Additional sensitivity analyses were performed for the analysis of AEs, including the MAEs comprising the primary endpoint: (A) on the per protocol (PP)

population, where patients who had dropped out of the study and had not experienced an AE of a given category were removed from the analysis of the respective AE category and (B) on the PP population, additionally excluding a centre classified as UCC that had changed its standard procedures after commencing to enrol patients, so that it would no longer have qualified as UCC.

The number of patients included in the sensitivity analyses varied depending on the respective AE that was analysed.

Analyses

For the primary endpoint analysis, the incidence of MAEs was calculated as the percentage of patients experiencing at least 1 MAE (crude rates) along with the exact binomial 95% CIs. The two treatment groups were compared using χ^2 or Fisher's exact test as appropriate and ORs were calculated. A multivariable logistic regression model was used to adjust for variables that were likely to influence the risk of experiencing an MAE, that is, sex, age, comorbidity (CCI), preoperative falls (within the last 3 months), type of initial surgery (osteosynthesis vs endoprosthesis), and residential status at baseline (community dwelling vs non-community dwelling).

To analyse changes over time for mobility and quality of life, mixed effects models for repeated measures with an unstructured covariance were used, adjusting for the same parameters as the logistic regression model and, if available, for baseline scores of the respective parameter. Significance tests were based on differences in least squares means.

Further categorical variables were analysed with χ^2 and Fisher's exact test and numerical variables with the Wilcoxon rank-sum and the t-test, as appropriate.

Survival was analysed using a Kaplan-Meier plot and the logrank test.

All statistical tests were two-sided and at a significance level of 5%. SAS software, V.9.4 (SAS Institute, Cary, North Carolina, USA) was used for analysis.

RESULTS

Of 281 patients enrolled, 142 were treated in GFCs and 139 in UCCs. Within 1 year of surgery, 35 patients died, 20 (14.1%) in GFCs and 15 (10.8%) in UCCs (figure 1).

Baseline characteristics

Most baseline characteristics were similarly distributed in both groups (table 1). Patients treated in GFCs were slightly younger with a mean age of 81.9 (SD, 6.6) years versus 83.9 years (SD 6.9) in patients treated in UCCs (p=0.013) and suffered from slightly more comorbidities with a mean CCI of 2.0 (SD, 2.1) versus 1.2 (SD, 1.5) in the UCC group (p=0.001). In the GFC group, 63 (48.1%) patients were reported having sustained a fall within 3 months before surgery compared with 35 (26.1%) in the UCC group (p<0.001). However, the number of preoperative fragility fractures was comparable (online supplemental eTable 1).

Primary outcome

The primary endpoints of this study were the prespecified MAEs delirium, congestive heart failure, pneumonia,

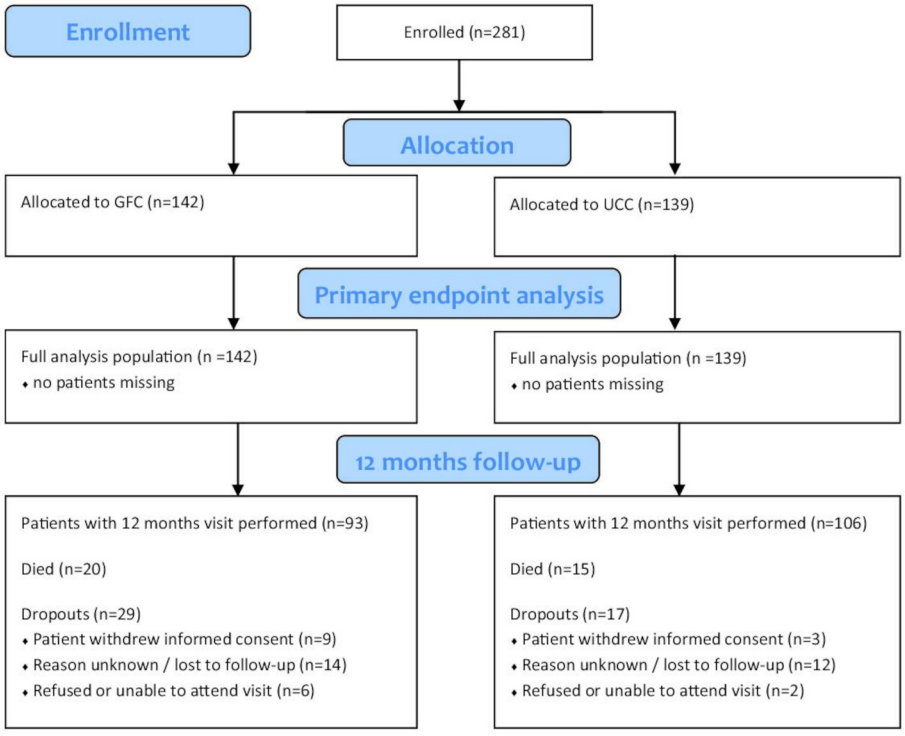

Figure 1 Study flow chart. GFC, geriatric fracture centre; UCC, usual care centre.

Table 1 Baseline characteristics: sociodemographics, Charlson Comorbidity Index, history of previous falls and residential status

Variable	Full analysis population			Full analysis population with 1 year visit done		
	GFC N=142	UCC N=139	*P* value	GFC N=93	UCC N=106	*P* value
Gender, n (%)	142	139	0.212*	93	106	0.394*
Female	100 (70.4)	107 (77.0)		68 (73.1)	83 (78.3)	
Male	42 (29.6)	32 (23.0)		25 (26.9)	23 (21.7)	
Age (years)*			0.013†			0.014†
n	142	139		93	106	
Mean (SD)	81.9 (6.6)	83.9 (6.9)		81.1 (6.5)	83.5 (6.7)	
Median (Q1; Q3)	82.0 (77.0; 86.0)	84.0 (79.0; 89.0)		82.0 (75.0; 84.0)	84.0 (79.0; 88.0)	
Min; Max	70.0; 98.0	70.0; 100.0		71.0; 98.0	71.0; 100.0	
Race, n (%)	142	139	0.543‡	93	106	0.655‡
Caucasian	91 (64.1)	84 (60.4)		53 (57.0)	60 (56.6)	
Black	2 (1.4)	1 (0.7)		0 (0.0)	1 (0.9)	
Asian	49 (34.5)	52 (37.4)		40 (43.0)	43 (40.6)	
Mixed	0 (0.0)	0 (0.0)		0 (0.0)	0 (0.0)	
Other	0 (0.0)	2 (1.4)		0 (0.0)	2 (1.9)	
Does the patient currently smoke?, n (%)	142	139	0.481*	93	106	0.421‡
No	132 (93.0)	132 (95.0)		89 (95.7)	104 (98.1)	
Yes	10 (7.0)	7 (5.0)		4 (4.3)	2 (1.9)	
Charlson Comorbidity Index			0.001†			0.003†
n	142	139		93	106	
Mean (SD)	2.0 (2.1)	1.2 (1.5)		1.9 (1.9)	1.1 (1.4)	
Median (Q1; Q3)	1.0 (1.0; 3.0)	1.0 (0.0; 2.0)		1.0 (1.0; 3.0)	1.0 (0.0; 2.0)	
Min; Max	0.0; 11.0	0.0; 8.0		0.0; 9.0	0.0; 8.0	
Did the patient experience any falls within the last 3 months?, n (%)	131	134	<0.001*	85	104	<0.001*
No	68 (51.9)	99 (73.9)		44 (51.8)	81 (77.9)	
Yes	63 (48.1)	35 (26.1)		41 (48.2)	23 (22.1)	
Residential status (at baseline), n (%)	142	139	0.646*	93	106	0.279*
Community dwelling	122 (85.9)	122 (87.8)		88 (94.6)	96 (90.6)	
Non-community dwelling	20 (14.1)	17 (12.2)		5 (5.4)	10 (9.4)	

*χ^2 test.
†*t* test.
‡Fisher's exact test.
GFC, geriatric fracture centre; UCC, usual care centre.

deep venous thrombosis, pulmonary embolism, pressure ulcers, and myocardial infarction, for which unadjusted ORs are presented in table 2. During the first year after surgery, any of these MAEs occurred in a higher proportion of patients (p<0.001) in the GFC group (40/142, 28.2%) compared with the UCC group (11/139, 7.9%) with an OR of 4.56 (95% CI 2.23 to 9.34). Analysing individual MAEs, pneumonia (GFC: 13/142, 9.2%; UCC: 4/139, 2.9%; OR, 3.40 (95% CI 1.08 to 10.70), p=0.027) and delirium (GFC: 16/142, 11.3%; UCC: 3/139, 2.2%, OR, 5.76 (95% CI 1.64 to 20.23), p=0.002) occurred more often in the GFC group, whereas no significant differences were seen for other MAEs. In the multivariable logistic regression model analysing the occurrence of 'any MAE', only 'treatment group' had a significant effect (OR, 4.08; 95% CI 1.87 to 8.88; p<0.001) (online supplemental eTable 2). The sensitivity analyses confirmed these findings (online supplemental eTables 2 and 3).

Analysing only MAEs that occurred during the stay in acute care, a significant difference between the groups was only present for delirium (GFC: 14/142, 9.9%; UCC: 3/139, 2.2%; OR, 4.96 (95% CI 1.39 to 17.66); p=0.007) (table 2).

Secondary outcomes

Adverse events

No statistically significant difference was detected between the groups in the incidence of all but 2 categories of AEs

Table 2 Major adverse events (MAEs) and other adverse events (AEs) (patient level, full analysis population)

	Treatment group					
	GFC N=142		UCC N=139			
Adverse event	n*	%†(95% CI‡)	n*	%†(95% CI‡)	ORs§ (95% CI)	*P* value
MAEs occurring in the first year after surgery						
Any MAE	40	28.2 (20.9 to 36.3)	11	7.9 (4.0 to 13.7)	4.56 (2.23 to 9.34)¶	<0.001**
Delirium	16	11.3 (6.6 to 17.7)	3	2.2 (0.4 to 6.2)	5.76 (1.64 to 20.23)¶	0.002**
Congestive heart failure	6	4.2 (1.6 to 9.0)	2	1.4 (0.2 to 5.1)	3.02 (0.53 to 31.02)††	0.282‡‡
Pneumonia	13	9.2 (5.0 to 15.1)	4	2.9 (0.8 to 7.2)	3.40 (1.08 to 10.70)¶	0.027**
Deep venous thrombosis	3	2.1 (0.4 to 6.0)	1	0.7 (0.0 to 3.9)	2.98 (0.24 to 157.47)††	0.622‡‡
Pulmonary embolism	4	2.8 (0.8 to 7.1)	0	0.0 (0.0 to 2.6)	–	0.122‡‡
Pressure ulcers (>2 cm in diameter)	4	2.8 (0.8 to 7.1)	2	1.4 (0.2 to 5.1)	1.99 (0.28 to 22.24)††	0.684‡‡
Myocardial infarction	3	2.1 (0.4 to 6.0)	0	0.0 (0.0 to 2.6)	–	0.247‡‡
MAEs occurring during the stay in the orthopaedics/ trauma unit						
Any MAE	21	14.8 (9.4 to 21.7)	7	5.0 (2.0 to 10.1)	3.27 (1.34 to 7.97)¶	0.006**
Delirium	14	9.9 (5.5 to 16.0)	3	2.2 (0.4 to 6.2)	4.96 (1.39 to 17.66)¶	0.007**
Congestive heart failure	2	1.4 (0.2 to 5.0)	1	0.7 (0.0 to 3.9)	1.97 (0.10 to 117.14)††	1.000‡‡
Pneumonia	3	2.1 (0.4 to 6.0)	1	0.7 (0.0 to 3.9)	2.98 (0.24 to 157.47)††	0.622‡‡
Deep venous thrombosis	0	0.0 (0.0 to 2.6)	1	0.7 (0.0 to 3.9)	0.00 (0.00 to 18.60)††	0.495‡‡
Pulmonary embolism	2	1.4 (0.2 to 5.0)	0	0.0 (0.0 to 2.6)	–	0.498‡‡
Pressure ulcers (>2 cm in diameter)	0	0.0 (0.0 to 2.6)	1	0.7 (0.0 to 3.9)	0.00 (0.00 to 18.60)††	0.495‡‡
Myocardial infarction	2	1.4 (0.2 to 5.0)	0	0.0 (0.0 to 2.6)	–	0.498‡‡
Adverse events other than MAEs occurring in the first year after surgery						
Any AE	79	55.6 (47.1 to 64.0)	63	45.3 (36.9 to 54.0)	1.51 (0.95 to 2.42)¶	0.084**
Surgical adverse events	6	4.2 (1.6 to 9.0)	7	5.0 (2.0 to 10.1)	0.83 (0.27 to 2.54)¶	0.746**
Medical adverse events	35	24.6 (17.8 to 32.6)	23	16.5 (10.8 to 23.8)	1.65 (0.92 to 2.97)¶	0.093**
Other AEs	61	43.0 (34.7 to 51.5)	48	34.5 (26.7 to 43.1)	1.43 (0.88 to 2.31)¶	0.147**
Adverse events other than MAEs occurring during the stay in the orthopaedics/ trauma unit						
Any AE	41	28.9 (21.6 to 37.1)	33	23.7 (16.9 to 31.7)	1.30 (0.76 to 2.22)¶	0.329**
Surgical adverse events	1	0.7 (0.0 to 3.9)	0	0.0 (0.0 to 2.6)	–	1.000‡‡
Medical adverse events	22	15.5 (10.0 to 22.5)	11	7.9 (4.0 to 13.7)	2.13 (0.99 to 4.59)¶	0.048**
Other AEs	11	7.7 (3.9 to 13.4)	20	14.4 (9.0 to 21.3)	0.50 (0.23 to 1.09)¶	0.076**

*Number of patients with at least one AE. If a patient experienced multiple AEs under the same AE class, the patient was only counted once.
†Estimated risk of developing at least one AE (calculated by dividing the number of patients experiencing at least one AE by the total number of patients).
‡CIs for percentages were calculated using the exact method (Clopper Pearson method).
§OR comparing geriatric fracture centre (GFC) against usual care centre (UCC).
¶Confidence intervals were calculated using the Wald method.
**χ^2 test.
††CIs were calculated using the exact method.
‡‡Fisher's exact test.

other than the predefined MAEs (online supplemental eTables 4a and 4b). During the stay in the acute ward, anaemia was reported for 6 (4.2%) patients in GFCs but for no patient in UCCs (p=0.030). Injuries resulting from falls after leaving the hospital were reported for 10 (7.0%) patients treated in GFCs but for no patient treated in UCCs (p=0.002). Grouping AEs other than MAEs into 'surgical', 'medical', and 'other' revealed a slight statistically significant difference for medical AEs during the stay in the acute ward (table 2). These were reported for 22/142 (15.5%) patients treated in GFCs and for 11/139 (7.9%) patients treated in UCCs (p=0.048). The driving variable for this difference was anaemia (online supplemental eTable 4b).

Perioperative variables

Most perioperative variables (table 3) as well as surgical parameters (online supplemental eTable 5) were comparable

Table 3 Perioperative information (full analysis population)

Variable	Treatment group GFC N=142	UCC N=139	*P* value
Time from injury to hospital admission (days)	142	139	0.270*
Mean (SD)	1.0 (4.1)	1.2 (5.5)	
Median (Q1; Q3)	0.0 (0.0; 1.0)	0.0 (0.0; 0.0)	
Min; Max	0.0; 42.0	−2.0; 51.0	
Time from hospital admission to surgery (hours)	142	139	<0.001*
Mean (SD)	33.9 (26.0)	72.0 (77.8)	
Median (Q1; Q3)	28.0 (19.0; 40.0)	43.0 (22.0; 92.0)	
Min; Max	2.0; 155.0	3.0; 513.0	
Length of surgery: from incision to closure (min)	142	139	0.904*
Mean (SD)	75.9 (35.2)	75.1 (33.1)	
Median (Q1; Q3)	70.0 (50.0; 95.0)	70.0 (50.0; 92.0)	
Min; Max	18.0; 227.0	25.0; 175.0	
Duration of hospital stay from admission to discharge from orthopaedic/trauma department (nights)	141	137	<0.001*
Mean (SD)	8.4 (4.7)	12.9 (5.7)	
Median (Q1; Q3)	7.0 (6.0; 10.0)	12.0 (9.0; 16.0)	
Min; Max	2.0; 42.0	3.0; 30.0	
Type of anaesthesia, n (%)	142	139	0.183†
Spinal	69 (48.6)	71 (51.1)	
General	69 (48.6)	68 (48.9)	
Other‡	4 (2.8)	0 (0.0)	
Type of initial surgery, n (%)	142	139	0.261§
Endoprosthesis	49 (34.5)	57 (41.0)	
Osteosynthesis	93 (65.5)	82 (59.0)	

*Wilcoxon rank sum test.
†Fisher's exact test.
‡other: 1 general and ilioinguinal, 1 general with spinal block, 1 epidural block, 1 femoral nerve block and general.
§χ^2 test.
GFC, geriatric fracture centre; UCC, usual care centre.

in both groups. In the GFC group, 93/142 (65.5%) patients were treated with osteosynthesis and 49/142 (34.5%) with an endoprosthesis, whereas in the UCC group, 82/139 patients (59.0%) underwent osteosynthesis and 57/139 (41.0%) received an endoprosthesis (p=0.261).

Differences were found in the time elapsing between hospital admission and surgery, which was significantly shorter in the GFC group with a median (Q1; Q3) of 28.0 hours (19.0; 40.0) vs 43.0 hours (22.0; 92.0) in the UCC group (p<0.001) and the length of the stay in the orthopaedic/ trauma unit, which was also significantly shorter in the GFC group with a median (Q1; Q3) of 7 nights (6; 10) versus 12 nights (9; 16) in the UCC group (p<0.001).

Mortality

Mortality 1 year after surgery was also similar in both groups with rates of 14.8% (95% CI 9.8 to 22.0) in the GFC group and 11.5% (95% CI 7.1 to 18.3) in the UCC group (p=0.456) (online supplemental eFigure 1). During the stay in acute care, 1/142 (0.7%) patient (95% CI 0.0 to 3.9) from a GFC and 2/139 (1.4%) patients (95% CI 0.2 to 5.1) from a UCC died.

Mobility and quality of fife

Mobility, that is, PMS and TUG test, improved significantly over time in both groups (online supplemental eTable 6). Both parameters were significantly better in the GFC group than in the UCC group at 1 year, and the TUG test also at 12 weeks (figure 2).

Like mobility, quality of life improved significantly over time in both groups (online supplemental eTable 6). However, no significant difference between the groups was detected at any time point (figure 2).

DISCUSSION

In this study comparing outcomes of patients 70 years or older treated in GFCs and UCCs for proximal femur

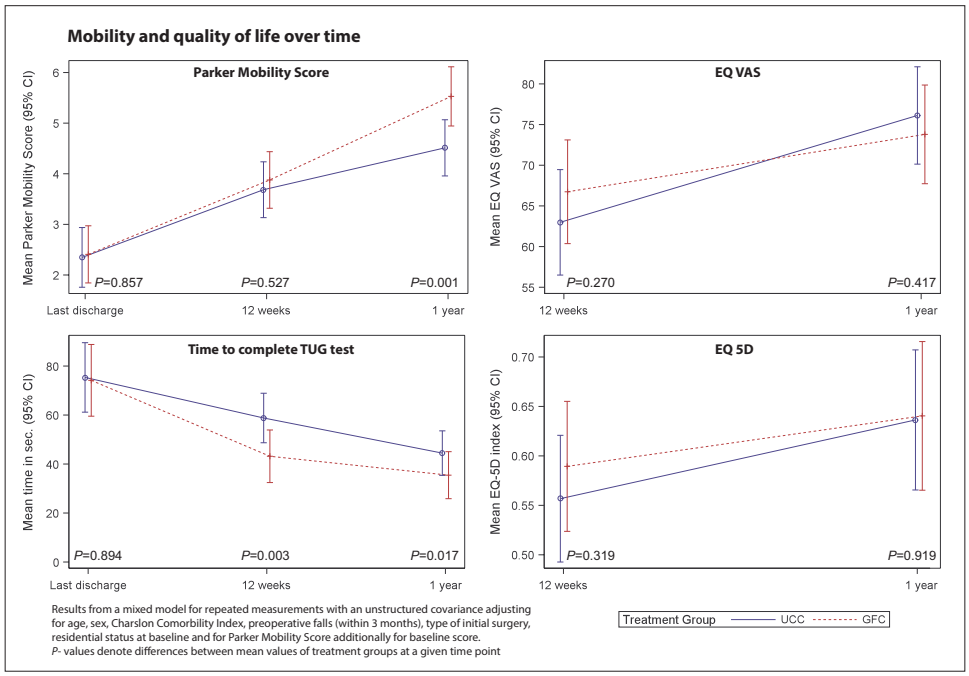

Figure 2 Mobility (Parker Mobility Score and timed up and go test) and quality of life (EQ VAS and EQ-5D) over the course of follow-up.

fractures, more patients in the GFC group than in the UCC group experienced MAEs.

During time spent in acute care, delirium was the only MAE reported more frequently in GFCs. For the complete study period, in addition to delirium, pneumonia was reported more often in the GFC group.

The incidence of in-hospital delirium was 9.9% in GFCs and 2.2% in UCCs, which is low, considering that in general, 10%–85% of hospitalised older patients develop the condition.

The higher delirium rate in GFCs corresponds to the findings of Folbert *et al* and Kusen *et al*, who also reported an increase in delirium detection after introducing geriatric comanagement.[3 33] Folbert *et al* report incidences of 39% and 33%, whereas Kusen *et al* observed 13% and 2% in GFCs and UCCs, respectively. Delirium has a multifactorial aetiology and is often associated with loss of function and increased mortality.[34 35] It is often underdiagnosed, so that in the absence of proactive monitoring, up to 70% of patients with delirium may not be identified.[36] Appropriate training of staff has been shown to enhance detection[35 37] and appropriate treatment can have a significant impact on its progression. Therefore, early recognition is vital.[38]

In our study, the standardised CAM was carried out on suspicion of delirium. We have no medical explanation for higher delirium incidences in GFCs. However, one of the typical differences between GFCs and UCCs is the specialised training of staff along with closer monitoring of patients as part of the interdisciplinary team effort. Therefore, we hypothesise that staff in GFC wards have a higher ability to recognise age-related issues. Hence, they are more likely than staff in UCC wards to suspect the presence of delirium, in particular hypoactive delirium. This interpretation is supported by the higher rate at which anaemia as well as fall related AEs were reported from GFCs.

Anaemia was reported in 6/142 (4.2%) patients during the stay in the acute ward and in 7/142 (4.9%) patients of patients during the first year after surgery in the GFC group. In contrast, in the UCC group, anaemia was not reported for a single patient during the stay in the acute ward and only in 1/139 (0.7%) patients during the first year after surgery. These figures are very low. According to a comprehensive metaanalysis on 45 original publications, the overall prevalence of anaemia in older patients is as high as 17% and rises with age.[39] A recent position paper of the German Geriatric Society describes anaemia as 'frequent but still under-estimated in geriatric patients'.[40] Underdiagnosing appears to be common. A study as recent as 2019 analysed information taken from patient charts and compared the documentation of haemoglobin levels with the corresponding anaemia related ICD9CM description codes. They found that only 14.7% of patients with haemoglobin levels qualifying for anaemia were actually documented with the corresponding ICD9CM code.[41] Bearing in mind that in our study, we had not given specific guidance for the documentation of anaemia, it was solely up to the study centre whether a finding of low haemoglobin would be interpreted as anaemia and documented as such. Putting the anaemia findings of our study in the context of widely reported prevalences and underreporting leads us to believe that the apparent differences are based on underdiagnosis in UCCs.

Injuries resulting from a fall after discharge and falls occurring in the 3 months before surgery were also reported at higher rates in GFCs. Considering that the incidence of preoperative fragility fractures was similar in both groups, it seems likely that the different fall incidences result from detection bias. Fall-related AEs are difficult to detect because there are significant psychological barriers for older people to report falls. Interviewers must overcome these barriers to receive reliable information. Staff in GFC wards are specialised in dealing with geriatric patients, so they are more likely to receive honest answers than staff in UCC wards.

Thus, the most plausible explanation for the seemingly higher incidence of delirium as well as anaemia and fall-related injuries in GFCs is improved detection. Since improved detection facilitates improved treatment, we interpret these findings in favour of GFCs, even though not in line with our study hypothesis.

On the other hand, we could not find a medical explanation for the higher incidence of pneumonia in the GFC group during the first year after surgery, in particular because in the same time period, the patients from the GFC group displayed better mobility in the PMS and in the TUG test. The absence of a difference in the incidence of MAEs other than delirium and pneumonia is in line with several publications, which report similar complication rates in GFCs and UCCs.[11 13 33 42–44] Notwithstanding, other studies report less complications in GFCs,[3 12 45–47] so the currently available evidence remains inconclusive.

Several other parameters in our study were in favour of GFCs. The time from hospital admission to surgery and the length of stay in acute care were shorter in the GFC group. This demonstrates that the organisational changes in GFCs are indeed effective, which corresponds with other reports.[3 33 43 45 48–50]

In spite of the higher mean age and baseline CCI in GFCs, there was no significant difference in mortality rates, which were generally low. Various other studies with a randomised design[11 14] or a historical control group,[33] whose populations did not differ concerning age or comorbidity, have also reported the absence of significant differences in mortality 1 year after surgery. We rate the absence of a higher mortality in spite of the higher age and CCI in the GFC group as another indication for the success of the model.

Further, we observed no differences in the EQ-5D or the EQ-VAS between the groups 1 year after surgery. To the best of our knowledge, only two other publications have addressed quality of life. Shuy *et al* report a better physical component score of the SF 36[14] and Prestmo *et al* report a better EQ-5D for patients treated in GFCs.[11]

Additionally, our analysis showed better mobility 1 year after surgery for patients treated in GFCs in both the TUG test, which determines functional ability,[27] and the PMS, which specifically targets ambulation as required for independent living. The interdisciplinary approach of geriatric comanagement specifically addresses topics like nutrition and early mobilisation. Both may have a positive effect on sarcopenia, thus contributing to a long-lasting improvement in mobility. So far, only a few publications on this topic have addressed walking ability, and all reported outcomes were favourable for GFCs.[11 14 51]

Improved ability to walk appears to be a plausible effect of treatment in a GFC. GFCs are not only characterised by specific diagnostic and treatment algorithms that entail developing individual rehabilitation concepts for the time after discharge from acute care. More importantly, staff in GFCs has been specially trained to detect age-related health issues with the aim of improving patients' general health and quality of life, as well as to enhance their ability to live independently. Beyond the obvious benefits for the individual patient, this approach has also been shown to be cost-effective.[11] The topic of cost-effectiveness goes beyond the scope of the present publication. However, based on the comprehensive data collection in this study, an analysis on cost- effectiveness is currently getting prepared for an additional publication.

Strengths and limitations

Our study has several limitations. Above all, the international multicentre design did not permit us to randomise patients, because this would have required to have both a UCC and a GFC available in the same location so that patient allocation could take place upon hospital admission. Additionally, given the previously published evidence on the positive effect of GFCs, it would have been unethical to randomise patients to a UCC, so IRB approvals could have presented an obstacle. Thus, we allocated patients per standard of local care, so that regional referral policies to specific hospitals may have introduced unknown confounders and thus a selection bias. However, we had chosen this design because in contrast to a randomised trial, it allowed us to compare the 'real world' standard of care in contemporary UCCs with GFCs in different geographical regions. Since this has not been done before, it enhances the generalisability of our results, especially since our inclusion criteria were broad and our sample size large. Most of the currently published studies were monocentre or compared two hospitals from the same country; only a handful were randomised. Moreover, many studies analysed outcomes from the same hospital before and after introduction of geriatric co-management, which fails to reflect the progress made in clinical practice in the absence of dedicated geriatric co-management.

As a result of our non-randomised design, the treatment groups were unequal concerning age and CCI, which were both higher in patients treated in GFCs. We addressed this with a multivariable model on our primary outcome, the MAEs. The model controlled for various potential confounders, including age and CCI. No effect of age or CCI on the total MAE rate was revealed. That said, the higher age and CCI in the GFC group did not result in significant differences in 1-year mortality.

Another important limitation is the potential contamination through the introduction of improved hospital

procedures in the time frame in which the study was conducted. Even in the absence of formal changes, GFC principles are currently becoming the usual standard of care. This is important to note, because the patients in this study were operated between June 2015 and January 2017. Most likely, the differences between GFCs and UCCs in a study conducted today would be smaller than at the time our study was performed. We tried to address potential contamination by closely documenting standard practices, for example, the frequency and timing of geriatricians' visits. This led to the identification of a centre that had changed its procedures so it would no longer have qualified as UCC. This centre was excluded in an additional sensitivity analysis. However, the results of the sensitivity analysis were similar to those performed with the full analysis population.

Additionally, missing data generally present a challenge for research in this age group, and our treatment groups were slightly imbalanced regarding the potential confounders age, comorbidities and preoperative falls. We addressed these issues with multivariable analyses including mixed-effects models, thereby adjusting for confounders and accounting for missing values.

Another problem in this study was the risk of detection bias. In one of our study arms, namely GFCs, typically, staff was specifically trained to identify age-specific issues. Several age-specific issues were defined as outcome parameters in this study, for example, delirium, aneamia, and injuries related to postoperative falls. That said, reporting of many age-specific issues is problematic. A lack of appropriate training may lead to underreporting. Taking delirium as an example, unbiased detection could be facilitated through structured proactive monitoring in both GFCs and UCCs. However, the mere act of monitoring would alter the usual standard of care in UCCs. Our study had an observational design because we wanted to compare the GFC and UCC setting without interfering with the respective standard of care. Thus, defining pro-active monitoring for delirium for both study arms would have been self-defeating for our study aim.

CONCLUSIONS

Contrary to our study hypothesis, the rate of MAEs in the first year after surgery was higher in GFCs than in UCCs. Delirium was revealed as the main contributor. Most likely, this was based on improved detection in GFC centres rather than a truly elevated incidence. In spite of the higher mean age, mean CCI, and MAE rate in the GFC group, there was no difference between the groups with regard to mortality. These findings support continued adoption of the GFC model.

Additionally, several clinical and hospital workflow-related outcomes were in favour of GFCs, namely mobility, length of stay in acute care, and time from admission to surgery.

Based on its unique international multicentre setting, this is the first study that clearly demonstrates the benefits of geriatric co-management in a 'real world environment'.

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