Orthogeriatric Trauma Unit Improves Patient Outcomes in Geriatric Hip Fracture Patients

Henk Jan Schuijt, MD1,2, Jip Kusen, BSc1,2, Jan Jonas van Herhen, MD1, Puck van der Vet, BSc1,2, Olivia Geraghty, MD, PhD3, Diederik Pieter Johan Smeeing, MD, PhD1, and Detlef van der Velde, MD, PhD1

Abstract

Introduction: An aging population in developed countries has increased the number of osteoporotic hip fractures and will continue to grow over the next decades. Previous studies have investigated the effect of integrated orthogeriatric trauma units and care model on outcomes of hip fracture patients. Although all of the models perform better than usual care, there is no conclusive evidence which care model is superior. More confirmative studies reporting the efficacy of orthogeriatric trauma units are needed. The objective of this study was to evaluate outcomes of hip fracture patients admitted to the hospital before and after implementation of an orthogeriatric trauma unit. Materials and methods: This retrospective cohort study was conducted at a level 2 trauma center between 2016 and 2018. Patients aged 70 years or older with a hip fracture undergoing surgery were included to evaluate the implementation of an orthogeriatric trauma unit. The main outcomes were postoperative complications, patient mortality, time spent at the emergency department, time to surgery, and hospital length of stay. Results: A total of 806 patients were included. After implementation of the orthogeriatric trauma unit, there was a significant decrease in postoperative complications (42% vs. 49% in the historical cohort, p = 0.034), and turnaround time at the emergency department was reduced by 38 minutes. Additionally, there was significantly less missing data after implementation of the orthogeriatric trauma unit. After correcting for covariates, patients in the orthogeriatric trauma unit cohort had a lower chance of complications (OR 0.654, 95% CI 0.471-0.908, p = 0.011) and a lower chance of 1-year mortality (OR 0.656, 95% CI 0.450-0.957, p = 0.029). Conclusions: This study showed that implementation of an orthogeriatric trauma unit leads to a decrease in postoperative complications, 1-year mortality, and time spent at the emergency department, while also improving the quality of data registration for clinical studies. Level of Evidence: Level III.

Keywords
orthogeriatric, trauma, fracture, hip, mortality, geriatric

Introduction

An aging population in developed countries has increased the number of osteoporotic hip fractures and will continue to grow over the next decades.1,2 The surgical management of these patients is complex due to age-related comorbidities. Complications that result from immobilization occur frequently during hospitalization, along with delirium and death.3,4 It is necessary to revise the present model of care, to manage the increasing numbers of hip fracture patients in the future.

1 Department of Surgery, Sint Antonius Hospital, Utrecht, the Netherlands
2 Department of Surgery, University Medical Center Utrecht, the Netherlands
3 Department of Internal Medicine and Geriatrics, Sint Antonius Hospital, Utrecht, the Netherlands

Corresponding Author:
Henk Jan Schuijt, MD, Department of Surgery, Sint Antonius Hospital, Postbus 2500, 3430 EM Nieuwegein, Utrecht, the Netherlands.
Email: hschuijt@bwh.harvard.edu
In literature, 3 models of orthogeriatric trauma care are described:

1. Orthopedic/surgical ward with routine geriatric consultation.
2. Geriatric ward with the orthopedic surgeon acting as a consultant.
3. Orthogeriatric trauma unit with shared responsibilities by the surgeon and the geriatrician.5,6

Previous studies have investigated the effect of integrated orthogeriatric trauma units on hip fracture patients. These orthogeriatric trauma units have shown to reduce both short-term and long-term mortality in hip fracture patients, as well as hospital length of stay (HLOS) and time to postoperative mobilization.5-10 Although all of the models mentioned above perform better than usual care, there is no conclusive evidence which care model is superior.5,6 Therefore, more confirmative studies reporting the efficacy of orthogeriatric trauma units are needed to ascertain a greater understanding of the impact of different orthogeriatric care models on patient outcomes.

The objective of this study was to study the effect of implementation of an orthogeriatric trauma unit on postoperative complications, time spent at the emergency department (ED), time to surgery, hospital length of stay, and mortality of hip fracture patients admitted to the hospital. The hypothesis of this study is that patients receiving care after implementation of the orthogeriatric trauma unit have a lower chance of postoperative complications.

Materials and Methods

This retrospective cohort study was conducted in a level 2 trauma center at St. Antonius hospital between January 1st, 2016 and December 31st, 2018. The orthogeriatric trauma unit was implemented on the first of January 2018. In this study, the 2018 cohort was compared to a historical cohort before the implementation of the orthogeriatric trauma unit. Although no orthogeriatric trauma unit was present before 2018, there was a geriatric awareness program that increased awareness for common complications during admission for these patients. The orthogeriatric trauma unit at St. Antonius hospital is a unit with shared responsibilities by the surgeon and the geriatrician, where multidisciplinary care is provided for geriatric fracture patients.

The complete care pathway and the interventions of the orthogeriatric trauma unit are shown in Supplemental Figure 1. Hip fracture patients are admitted from the ED to the orthogeriatric trauma unit within 1 hour of arrival at the hospital. In the ED, standard ECG, blood testing, and additional radiology studies are performed and used by both the geriatrician and trauma surgeon for further treatment (e.g., cause of the fall, underlying pathology and deficiencies, malnutrition, and osteoporosis). After admission, immediate consultation of a physical therapist, geriatrician, dietician, is initiated. The physical therapist focusses on early weight-baring after surgery and prevention of common complications of hip fracture surgery (e.g., deep breathing exercises to prevent pneumonia in debilitated patients). The geriatrician visits the patients daily on the ward and gives recommendations for treatment to the treating physician/physician assistant. Furthermore, the geriatrician evaluates patient medication in the setting of fall prevention. The clinical staff coordinate their efforts to reduce postoperative complications, HLOS, time to surgery, ED admission time, and to facilitate an adequate and early discharge (e.g., to a rehabilitation facility). The clinical staff meets twice a week for a multidisciplinary consultation to discuss treatment goals and a discharge plan. The goal is to have patients ready for discharge in 5-7 days. Additionally, there is a focus on careful data registration for all patients in every step of their treatment (i.e., at the ED, during admission, and follow-up) by using healthcare pathways that are built into the electronic patient records.

All patients aged 70 years or older admitted to the ED with a hip fracture (Orthopaedic Trauma Association classification...
31-A or 31-B) undergoing surgery were eligible for inclusion. Exclusion criteria were pathological hip fractures, total hip replacement surgery, and periprosthetic hip fractures. Treatment codes were used for the identification of eligible subjects and data collection. It was possible for patients to be included in the study twice if the second admittance was due to a fracture of the contralateral hip.

The following baseline characteristics were collected from electronic medical records: age, sex, prefracture diagnosis of dementia (diagnosed by a geriatrician or general practitioner), Katz Index of Independence in Activities of Daily Living score (Katz-ADL), prefracture living situation (i.e., independent at home, at home with assistance for activities of daily living, institutional care facility, or nursing home), type of fracture (i.e., medial femoral neck, trochanteric femur or subtrochanteric femur), and type of surgical procedure (i.e., hemiarthroplasty, cannulated hip screw, dynamic hip screw, intramedullary nail, or conservative treatment).

The primary outcome of this study was postoperative complications. A complicated course was defined as one or more of the following complications according to the Dutch Hip Fracture Audit guidelines: congestive heart failure (confirmed by chest radiograph), pressure ulcer (diagnosed by attending physician), delirium (diagnosed by either geriatrician or physician assistant of the consultative orthogeriatric trauma team), pulmonary embolism (CTA-confirmed), deep venous thrombosis (duplex ultrasound confirmed), renal insufficiency (>24 ml/min decrease in glomerular filtration rate (GFR) compared to GFR at admission), pneumonia (confirmed by chest radiograph or positive sputum culture), urinary tract infections (UTI) (positive urine culture), in-hospital falls and surgical wound infection (diagnosed by attending physician), and need for blood transfusion (i.e., patient received red blood cell transfusion).

Secondary outcomes were: time spent at the ED (in minutes, defined as the time between presentation to ED, and the time patient left the ED), time to surgery (in hours, defined as the time between presentation at ED, and time of surgery), hospital length of stay (in days, defined as the time between presentation at ED, and time of discharge from hospital), and patient mortality, with a follow-up period of 1 year. Mortality data were acquired by consulting the municipal citizen registry.

**Statistical Methods**

Previous studies have found a reduction in complications between 15% and 6%. A sample size of 776 patients was needed to detect a 10% difference in complications with a statistical power of 80% and a significance level (α) of 0.05.

Differences between patients who were admitted before and after the implementation of the orthogeriatric trauma unit were analyzed using descriptive statistics. Continuous variables were tested for differences between groups with an unpaired t-test or Mann-Whitney U test, depending on normality. Normality was tested using the Shapiro-Wilk test. All categorical and dichotomous data were tested with a chi-square test. Kaplan-Meier curves were constructed, and a Mantel-Cox (log-rank) test was performed to compare survival between the 2 groups.

A multivariable analysis was performed to correct for covariates. The following variables were selected for multivariable analysis: age, sex, diagnosis of dementia, and Katz-ADL. Age, sex and dementia were included in the multivariable analysis as covariates because they are known risk factors for complications and mortality. Katz-ADL score was included because of significant baseline differences between cohorts. Continuous predictor variables (i.e., age and Katz-ADL) were tested for linearity with a 2-tailed Pearson correlation test and had a linear correlation at the p < 0.05 level. Little’s missing completely at random (MCAR) test was performed for patterns of missing data. Data was not missing completely at random (p < 0.001), which was caused by a significant difference in missing data between cohorts. There was significantly more missing data in the historical cohort. This type of selective missing data pattern is called missing at random (MAR) and should be dealt with using multiple imputation. Missing data were imputed using the expectation-maximization technique (10 imputations). A binary logistic regression analysis was performed for complications and mortality to calculate odds ratios (OR) and 95% confidence intervals (CI). A multivariable regression analysis for continuous outcome variables (i.e., time at the ED, time to surgery, hospital length of stay) was not feasible, because these variables were non-normally distributed at the p < 0.001 level with the Shapiro-Wilk test. Additionally, there was too much data missing for these outcomes. All statistical analyses were done using IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., 2017, Armonk, NY). A p-value of <0.05 was set as significant for all tests. This paper was written in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

**Results**

For the historical cohort, 524 patients were included and a total of 282 patients were included in the orthogeriatric trauma unit cohort (Figure 1).

**Baseline Characteristics**

Median age was 85 years in the historical cohort (IQR 80-89) and 85 years in the orthogeriatric trauma unit cohort (IQR 80-90), p = 0.527 (Table 1). There were 380 female patients (73%) in the historical cohort and 199 (71%) in the orthogeriatric trauma unit cohort, p = 0.557. A total of 133 (26%) patients were diagnosed with dementia in the historical cohort, versus 77 (28%) in the orthogeriatric trauma unit cohort, p = 0.679. Patients in the historical cohort were less dependent at baseline in terms of Katz-ADL: median 0 (IQR: 0-2) in comparison to the patients in the orthogeriatric trauma unit cohort: median 3 (IQR: 0-5), p < 0.001. There were no significant differences between the 2 cohorts at baseline in terms of living situation, fracture type or surgical procedure.
After implementation of the orthogeriatric trauma unit, there was a significant decrease (42% vs. 49%, \( p = 0.034 \)) in the number of patients with a complicated course (Table 2). Median turnaround time at the ED was 160 minutes (IQR 110-228) in the orthogeriatric trauma unit cohort and 198 (IQR 142-257) in the historical cohort, \( p < 0.001 \). There were no significant differences in time to surgery, HLOS, or mortality in the univariable analysis.

**Survival Analysis**

The survival analysis is shown for both cohorts (Figure 2). The orthogeriatric trauma unit cohort showed an overall 30-day survival advantage.

---

**Table 1. Baseline Characteristics.**

| Baseline variable | Data missing n (%) | Orthogeriatric care unit cohort (n = 282) | Historical cohort (n = 524) | \( p \)-value |
|-------------------|--------------------|------------------------------------------|-----------------------------|--------------|
| Age; median (IQR) | 0 (0)              | 85 (80-90)                               | 85 (80-89)                  | 0.527*       |
| Female sex; n (%) | 0 (0)              | 199 (71)                                 | 380 (73)                    | 0.557        |
| Prior diagnosis of dementia; n (%) | 15 (2) | 77 (28)                                 | 133 (26)                    | 0.679        |
| KATZ-ADL score, median (IQR) | 160 (20) | 3 (0-5)                                  | 0 (0-2)                     | <0.001*      |
| **Living situation; n (%)** | 16 (2) | At home: 141 (50)                        | 238 (47)                    | 0.224        |
|                  |        | At home with ADL assistance: 55 (20)     | 130 (26)                    |              |
|                  |        | Nursing home: 33 (12)                   | 65 (13)                     |              |
|                  |        | Institutional care facility: 51 (18)    | 77 (15)                     |              |
| **Fracture type; n (%)** | 20 (3) | Medial femoral neck: 153 (57)           | 287 (55)                    | 0.091        |
|                  |        | Trochanteric femur: 109 (41)            | 228 (44)                    |              |
|                  |        | Subtrochanteric femur: 6 (2)            | 3 (1)                       |              |
| **Surgical procedure; n (%)** | 2 (0) | Conservative treatment: 0 (0)           | 2 (0)                       | 0.592        |
|                  |        | Hemiarthroplasty: 127 (45)              | 237 (45)                    |              |
|                  |        | Cannulated hip screw: 7 (3)             | 7 (1)                       |              |
|                  |        | Dynamic hip screw: 28 (10)              | 46 (9)                      |              |
|                  |        | Intramedullary nail: 120 (43)           | 230 (44)                    |              |

Statistically significant differences are shown in bold. *Mann Whitney U Test was performed for variables with a non-normal distribution at the \( p < 0.001 \) level (Shapiro-Wilk test).

**Abbreviations:** IQR; interquartile range, KATZ-ADL; Katz Index of Independence in Activities of Daily Living score, ADL; Activities of Daily Living.

**Table 2. Patient Outcomes Before and After Implementation of the Orthogeriatric Trauma Unit, Univariable Analysis.**

|                      | Missing n (%) | Orthogeriatric care unit cohort (n = 282) | Historical cohort (n = 524) | \( p \)-value | Relative reduction** |
|----------------------|--------------|------------------------------------------|-----------------------------|--------------|----------------------|
| Complication during admission; n (%) | 3 (0) | 117 (42)                                 | 257 (49)                    | 0.034        | 14%                  |
| Time spent at the ED in minutes; median (IQR) | 54 (7) | 160 (110-228)                           | 198 (142-257)               | <0.001*      | 19%                  |
| Time to surgery in hours; median (IQR) | 53 (7) | 20 (15-25)                               | 21 (16-25)                  | 0.343*       |                      |
| Hospital length of stay in days; median (IQR) | 42 (5) | 6 (4-10)                                 | 6 (4-9)                     | 0.284*       |                      |
| 30-day mortality; n (%) | 2 (0) | 26 (9)                                   | 47 (9)                      | 0.919        |                      |
| 90-day mortality; n (%) | 2 (0) | 47 (17)                                  | 88 (17)                     | 0.945        |                      |
| 1-year mortality; n (%) | 2 (0) | 75 (27)                                  | 153 (29)                    | 0.415        |                      |

Statistically significant differences are shown in bold. *Mann Whitney U Test was performed for variables with a non-normal distribution at the \( p < 0.001 \) level (Shapiro-Wilk test) **Relative reduction was calculated for significant results only

**Abbreviations:** ED; emergency department, IQR; interquartile range

---

![Figure 2. Kaplan Meier analysis.](image)
The Survival functions between the cohorts were not statistically different (log-rank test). In this study, time spent at the ED was reduced by 38 minutes (19%) after implementation of the orthogeriatric trauma unit. A previous study reported no significant reduction in time spent at the ED, although it may have been underpowered.

In this study, hospital length of stay was not reduced after the implementation of the orthogeriatric trauma unit. A systematic review and meta-analysis compared 18 studies and found an average reduction in hospital length of stay of 0.25 days after implementation of geriatric care models. However, the clinical relevance of such a marginal reduction is debatable. A randomized controlled trial comparing orthogeriatric care and usual care for hip fracture patients found a reduction in HLOS of 1.7 days. Median time to surgery after the implementation of the orthogeriatric trauma unit was within 24 hours of presentation. Time to surgery over 24 hours is associated with more postoperative complications. Time to surgery is not routinely collected in studies investigating the efficacy of geriatric trauma units, but previous studies that did investigate this outcome did not find any significant differences. Thus, a thorough geriatric workup does not appear to increase time to surgery.

This study showed that patients in the orthogeriatric trauma unit had a lower chance of 1-year mortality. This corresponds with the results of a systematic review and meta-analysis that showed that integrated orthogeriatric care pathways reduce 1-year mortality. In this study, differences in survival between groups became apparent after 90 days (Figure 2). The geriatric awareness program before the implementation may have reduced mortality in the historical cohort, thus resulting in bias that would underestimate the effect of implementation of orthogeriatric care in comparison to usual care.

### Table 3. Patient Outcomes, Multivariable Analysis.

| Outcome                        | Variable                                        | OR    | 95% CI          | p-value |
|-------------------------------|-------------------------------------------------|-------|-----------------|---------|
| Complication during admission | Treatment in orthogeriatric trauma unit         | 0.654 | 0.471-0.908     | 0.011   |
|                               | Age (per year increase)                         | 1.064 | 1.032-1.108     | <0.001  |
|                               | Male sex                                        | 0.964 | 0.700-1.327     | 0.822   |
|                               | Diagnosis of dementia                           | 0.954 | 0.649-1.403     | 0.811   |
|                               | Prefracture KATZ-ADL (per point increase)       | 1.052 | 0.953-1.162     | 0.308   |
| 30-day mortality              | Treatment in orthogeriatric trauma unit         | 0.795 | 0.465-1.389     | 0.421   |
|                               | Age (per year increase)                         | 1.068 | 1.026-1.112     | 0.001   |
|                               | Male sex                                        | 2.248 | 1.344-3.761     | 0.002   |
|                               | Diagnosis of dementia                           | 1.777 | 0.989-3.191     | 0.054   |
|                               | Prefracture KATZ-ADL (per point increase)       | 1.152 | 1.001-1.327     | 0.049   |
| 90-day mortality              | Treatment in orthogeriatric trauma unit         | 0.807 | 0.522-1.246     | 0.334   |
|                               | Age (per year increase)                         | 1.074 | 1.041-1.108     | <0.001  |
|                               | Male sex                                        | 2.393 | 1.596-3.589     | <0.001  |
|                               | Diagnosis of dementia                           | 1.598 | 1.004-2.542     | 0.048   |
|                               | Prefracture KATZ-ADL (per point increase)       | 1.110 | 0.995-1.239     | 0.062   |
| 1-year mortality              | Treatment in orthogeriatric trauma unit         | 0.656 | 0.450-0.957     | 0.029   |
|                               | Age (per year increase)                         | 1.077 | 1.049-1.106     | <0.001  |
|                               | Male sex                                        | 2.227 | 1.557-3.183     | <0.001  |
|                               | Diagnosis of dementia                           | 1.709 | 1.144-2.555     | <0.001  |
|                               | Prefracture KATZ-ADL (per point increase)       | 1.158 | 1.052-1.275     | <0.001  |

None of the multivariable models showed a significant lack of fit (Hosmer and Lemeshow test).

Abbreviations: OR; odds ratio, CI; confidence interval, KATZ-ADL; Katz Index of Independence in Activities of Daily Living score
Interpretation of Results

In this study, the implementation of an orthogeriatric trauma unit led to a decrease in complications. Although the effect was smaller than the 10% used in the power calculation, the sample size was large enough to detect this difference. The implementation of the orthogeriatric trauma unit may have led to better detection and registration of complications in comparison to the historical cohort. This possibility of detection bias may have led to an underestimation of the effect of orthogeriatric trauma unit on complications.

There were significantly more missing baseline data and outcome data in the historical cohort as described in the methods section ($p < 0.001$). This not surprising, as it is likely the result of better data registration for patients admitted to the orthogeriatric trauma unit. For example, there was a significant difference between the orthogeriatric trauma unit cohort and historical cohort in terms of Katz-ADL. Most of the missing data ($n = 116$) were in the historical cohort. This may be a possible source of bias, although this effect is not large because the overall amount of missing data is small and was imputed. This difference underscores that better data registration for patients admitted to the orthogeriatric trauma units will lead to higher quality data for clinical studies in the future.

A total of 69 patients were eligible for inclusion in the study, but were not admitted to the orthogeriatric trauma unit because the unit was at maximum capacity. These patients were younger at baseline (median 81 years, IQR 76-87) in comparison to patients admitted to the orthogeriatric trauma unit (median 85 years, IQR 80-90, $p = 0.011$), but there were no other baseline differences. This is a possible source of selection bias, because selective exclusion of younger patients may have led to an underestimation of the effect of the orthogeriatric trauma unit. The overall effect of this bias is likely to be small because the authors corrected for age and other covariates in the multi-variable analysis.

Strengths and Limitations

This study adds another high-quality study with a large sample size to evaluate the effect of orthogeriatric trauma units. Our study used time-to-event data, which allowed the construction of Kaplan-Meijer curves and survival analysis. A previous study described overall survival in geriatric patients with any fracture in an orthogeriatric trauma unit but did not make a comparison with a control group. This study is also the first to demonstrate a positive effect of process optimization after implementation of an orthogeriatric care model on time spent at the ED. Time spent at the ED is a relevant outcome measure because older patients with hip fractures are at risk for understessment of pain and poorer pain management when time spent at the ED is longer. A longer time spent at the ED is associated with longer time to surgery, which is in turn associated with poorer patient outcomes. The 19% reduction found in this study can help reduce the workload for both physicians and nurses at the ED. More importantly, it can improve the overall experience for the patient. Because for our patients, the waiting starts after they fall.

This study has a few limitations. Apart from mortality, only short-term outcomes were measured in this study because it is difficult to obtain a good follow-up for geriatric trauma patients, particularly in retrospective studies. Geriatric patient populations in clinical studies are very prone to selective loss to follow-up. Additionally, this study only collected traditional outcome measures (i.e., mortality, complications, etc.) but no patient-reported outcome measures or functional outcomes. There is some evidence that orthogeriatric care models can improve these outcomes as well. A randomized controlled trial investigating the effect of orthogeriatric care on patient reported outcome measures found an improved quality of life at 4 months and 12 months follow-up, as well as improved physical function. The authors advocate to use more patient-centered outcomes in future investigations and recommend that future studies in this field should include patient-reported outcome measures.

Conclusion

In conclusion, this study showed that implementation of an orthogeriatric trauma unit led to a decrease in postoperative complications, 1-year mortality, and time spent at the ED while also improving the quality of data registration for clinical studies. Although further studies are needed, physicians dealing with geriatric hip fracture patients regularly should consider integrating multidisciplinary orthogeriatric trauma care for their patients.

Authors’ Note

This study was approved by the local institutional review board and medical ethical committee of St. Antonius Hospital (registration number Z17.048). The Dutch Medical Research Involving Human Subjects Act (WMO) did not apply to this study. This study was carried out in accordance with the ethical standards laid down in the 1964 the World Medical Association Declaration of Helsinki and its later amendments.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Henk Jan Schuitj, MD ⓒ https://orcid.org/0000-0002-7399-6828

Supplemental Material

Supplemental material for this article is available online.
References

1. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury*. 2018;49(8):1458-1460. doi:10.1016/j.injury.2018.04.015

2. Marks R. Hip fracture epidemiological trends, outcomes, and risk factors background to the problem. *Int J Gen Med*. 2010;3:1-17. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2866546/pdf/jigm-3-001.pdf

3. Dolan MM, Hawkes WG, Zimmerman SI, et al. Delirium on hospital admission in aged hip fracture patients: prediction of mortality and 2-year functional outcomes. *J Gerontol A Biol Sci Med Sci*. 2000;55(9):M527-M534. http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=med4&NEWS=N&AN=109950510A&PAGE=reference&D=emed8&NEWS=N&AN=32010279

4. Bhandari M, Swiontkowski M. Management of acute hip fracture. *N Engl J Med*. 2017;377(21):2053-2062. doi:10.1056/NEJMcp1611090

5. Grigoryan KV, Javedan H, Ruhlman JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. *J Orthop Trauma*. 2014;28(3):1-13. doi:10.1097/BOT.0b013e3182a5a045

6. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in multidisciplinary team-based approach in geriatric hip fracture care: a systematic review. *J Am Acad Orthop Surg*. 2020;28(3):128-133. https://journals.lww.com/jaaos/Fulltext/2020/02010/Outcomes_in_Multidisciplinary_Team_based_Ap.9.aspx

7. Folbert EC, Hegeman JH, Vermeer M, et al. Improved 1-year mortality in elderly patients with a hip fracture following integrated orthogeriatric treatment. *Osteoporos Int*. 2017;28(1):269-277. doi:10.1007/s00198-016-3711-7

8. Vidán M, Serra JA, Moreno C, Riquelme G, Ortiz J. Efficacy of a comprehensive geriatric intervention in older patients hospitalized for hip fracture: a randomized, controlled trial. *J Am Geriatr Soc*. 2005;53(9):1476-1482. doi:10.1111/j.1532-5415.2005.53466.x

9. Friedman SM, Mendelson DA, Bingham KW, Kates SL. Impact of a comanaged geriatric fracture center on short-term hip fracture outcomes. *Arch Intern Med*. 2009;169(18):1712-1717. doi:10.1001/archinternmed.2009.321

10. Prestmo A, Hagen G, Sletvold O, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. *Lancet*. 2015;385(9978):1623-1633. doi:10.1016/S0140-6736(14)62409-0

11. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium—2018. *J Orthop Trauma*. 2018;32:S1-S10.

12. Katz S, Ford A, Moskowitz R, Jackson B, Jaffe M. Studies of illness in the aged: the index of ADL: a standardized measure of biological and psychosocial function. *JAMA*. 1963;185(12):914-919. http://dx.doi.org/10.1001/jama.1963.03060120024016

13. Voeten SC, Arends AJ, Wouters MWJM, et al. The dutch hip fracture audit: evaluation of the quality of multidisciplinary hip fracture care in the Netherlands. *Arch Osteoporos*. 2019;14(1):28. doi:10.1007/s11657-019-0576-3

14. Folbert ECE, Smit RS, van der Velde D, Regtuijt EMM, Klaren MH, Hegeman JHH. Geriatric fracture center: a multidisciplinary treatment approach for older patients with a hip fracture improved quality of clinical care and short-term treatment outcomes. *Geriatr Orthop Surg Rehabil*. 2012;3(2):59-67.

15. Kalas PHS, Koc BB, Hemmes B, et al. Effectiveness of a multidisciplinary clinical pathway for elderly patients with Hip fracture. *Geriatr Orthop Surg Rehabil*. 2016;7(2):81-85. doi:10.1177/2154185816645633

16. Friedman SM, Mendelson DA, Kates SL, McCann RM. Geriatric co-management of proximal femur fractures: total quality management and protocol-driven care result in better outcomes for a frail patient population. *J Am Geriatr Soc* 2008;56(7):1349-1356. doi:10.1111/j.1532-5415.2008.01770.x

17. Khorsaghi FA, Christmas C, Lee EJ, Mears SC, Wenz JFS. Effectiveness of a multidisciplinary team approach to hip fracture management. *J Surg Orthop Adv*. 2005;14(1):27-31.

18. Smith T, Pelpola K, Ball M, Ong A, Myint PK. Pre-operative indicators for mortality following hip fracture surgery: A systematic review and meta-analysis. *Age Ageing*. 2014;43(4):464-471. doi:10.1093/ageing/afu065

19. Tsuda Y, Yasunaga H, Horiguchi H, Ogawa S, Kawano H, Tanaka S. Association between dementia and postoperative complications after hip fracture surgery in the elderly: analysis of 87,654 patients using a national administrative database. *Arch Orthop Trauma Surg*. 2015;135(11):1511-1517. doi:10.1007/s00402-015-2321-8

20. Bai J, Zhang P, Liang X, Wu Z, Wang J, Liang Y. Association between dementia and mortality in the elderly patients undergoing hip fracture surgery: a meta-analysis. *J Orthop Surg Res*. 2018;13(1):298. doi:10.1186/s13018-018-0988-6

21. van der Heijden GJMG, T. Donders AR, Stijnen T, Moons KGM. Imputation of missing values is superior to complete case analysis and the missing-indicator method in multivariable diagnostic research: a clinical example. *J Clin Epidemiol*. 2006;59(10):1102-1109. doi:10.1016/j.jclinepi.2006.01.015

22. Greenland S, Finkle WD. A critical look at methods for handling missing covariates in epidemiologic regression analyses. *Am J Epidemiol*. 1995;142(12):1255-1264. doi:10.1093/oxfordjournals.aje.a117592

23. Donders ART, van Der Heijden GJMG, Stijnen T, Moons KGM. Review: a gentle introduction to imputation of missing values. *J Clin Epidemiol*. 2006;59(10):1087-1091. doi:10.1016/j.jclinepi.2006.01.014

24. von Elm E, Altman DG, Egger M, et al. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *PLOS Med*. 2007;4(10):1-5. doi:10.1371/journal.pmed.0040296

25. Pincus D, Ravi B, Wasserstein D, et al. Association between wait time and 30-day mortality in adults undergoing hip fracture surgery. *JAMA*. 2017;318(20):1994-2003. doi:10.1001/jama.2017.17606

26. Watne LO, Torbergsen AC, Conroy S, et al. The effect of a pre- and postoperative orthogeriatric service on cognitive function in...
27. Gosch M, Weltin YH, Roth T, Blauth M, Nicholas JA, Kammerlander C. Orthogeriatric co-management improves the outcome of long-term care residents with fragility fractures. *Arch Orthop Trauma Surg.* 2016;136(10):1403-1409. doi:10.1007/s00402-016-2543-4

28. Hwang U, Richardson LD, Sonuyi TO, Morrison RS. The effect of emergency department crowding on the management of pain in older adults with hip fracture. *J Am Geriatr Soc.* 2006;54(2):270-275. doi:10.1111/j.1532-5415.2005.00587.x

29. Frood J, Johnson T. Improving measures of hip fracture wait times: a focus on Ontario. *Surgery.* 2010;32(81):71.

30. Orosz GM, Magaziner J, Hannan EL, et al. Association of timing of surgery for hip fracture and patient outcomes. *J Am Med Assoc.* 2004;291(14):1738-1743. doi:10.1001/jama.291.14.1738

31. Klestil T, Röder C, Stotter C, et al. Impact of timing of surgery in elderly hip fracture patients: a systematic review and meta-analysis. *Sci Rep.* 2018;8(1):1-15. doi:10.1038/s41598-018-32098-7