VARIATION IN THE USE OF DIFFERENTIALLY-REIMBURSED HIP FRACTURE PROCEDURES

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CHAPTER 1: INTRODUCTION

I. Introduction

Geriatric hip fractures are a serious, common and disabling condition, with an estimated incidence of more than 266,000 hip fractures per year in the United States[1, 2]. Ninety percent of hip fractures occur in individuals age 65 or older, and almost all hip fractures (98%) are treated surgically[3]. Hip fractures are associated with significant morbidity and mortality[4-10]. Nearly one-third of elderly hip fracture patients die within a year of their hip fracture[4, 11] and less than half of patients ever regain their pre-fracture level of function[5, 10, 12]. The total annual costs of hip fracture-related treatment in the United States is estimated to be $18 billion annually[13-16].

As the primary payer for the nation's elderly, the burden of financing geriatric hip fracture treatment and rehabilitation in the United States falls primarily on to the Medicare program. Given the increasing proportion of the U.S. population that is becoming elderly and Medicare-eligible, the utilization of cost-effective treatments for geriatric patients is one of the main goals of the Medicare program[17]. The optimal treatment of geriatric hip fracture patients therefore aims to maximize functional recovery while minimizing complications and treatment costs.

Intertrochanteric hip fractures occur in the upper and outer portion of the femur between the greater and lesser trochanters. Intertrochanteric hip fractures account for nearly half of all elderly hip fractures (47%)[18-21]. The majority of intertrochanteric hip fractures are surgically treated with one of two types of internal fixation devices: a plate-with-screws (plate/screws) or an intramedullary nail (IMN) device. Clinical outcome studies have failed to demonstrate a significant benefit for the use of IMN over plate/screws implants in the majority of intertrochanteric hip fracture patients[22-32].

Since 1992, Medicare has paid surgeons more for IMN than plate/screws procedures in the treatment of intertrochanteric hip fracture patients. In contrast, Medicare pays hospitals under the same Diagnosis Related Groups (DRGs) for both the IMN and plate/screws procedures, although the IMN implants cost hospitals up to $1000 more per device than plate/screws[33, 34]. Thus, Medicare has generated competing payment incentives between surgeons and hospitals in the treatment of intertrochanteric hip fracture patients. Despite equivalent outcomes and higher implant-related complication rates[22, 23, 35], IMN use in the United States has continued to increase and now comprises approximately 60% of the internal fixation devices used to treat intertrochanteric hip fracture patients[34, 36, 37]. The effect of this ongoing provider payment incentive on IMN use among Medicare intertrochanteric hip fracture patients has not previously been examined using a comprehensive Medicare data base.

The following series of papers examine the patient, surgeon and hospital factors that were associated with IMN use, the geographic variation in IMN use, and the association between provider volume and short-term mortality following surgical treatment of Medicare intertrochanteric hip fracture patients during 2000 through 2002.

II. **Conceptual model:** Figure 1.1

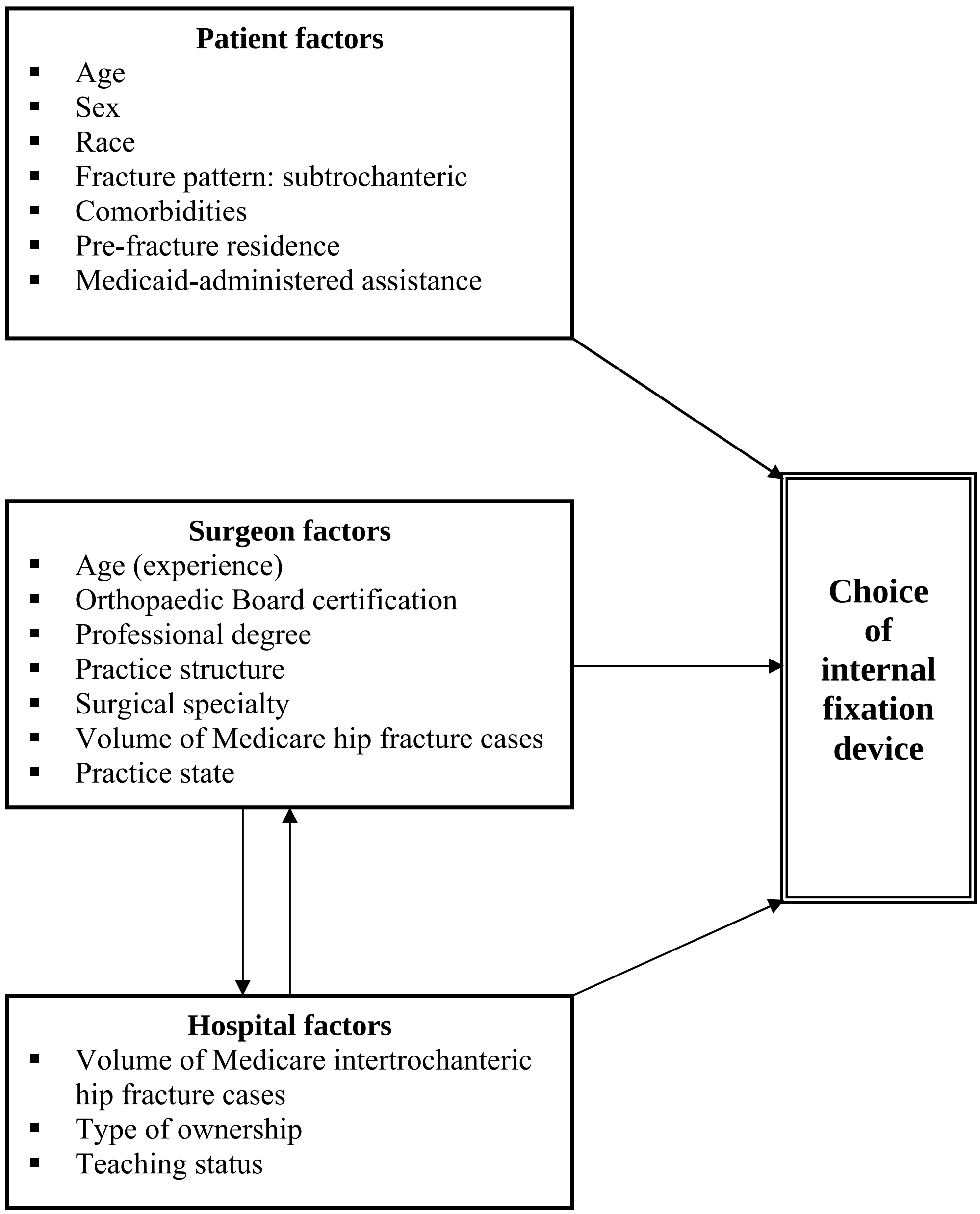
Three main groups of factors influence the type of internal fixation implant a patient receives for treatment of their hip fracture: patient, surgeon and hospital factors.

Although the treating surgeon ultimately selects the implant deemed best for a hip fracture patient, multiple patient characteristics are considered by the treating surgeon in surgical decision-making. In addition to specific fracture characteristics, patient factors such as bone density, age, severity of coexisting medical conditions, functional ability, cognitive status, living situation and level of social support may impact surgeons' implant decisions. Since the orthopedic literature is often limited exclusively to fracture patterns as they relate to device choices, we instead considered all available patient factors which are known or believed to be related to clinical outcomes after hip fracture. The model includes patient age, sex, race, subtrochanteric fracture, comorbidities, pre-fracture residence and Medicaid-administered assistance as possible predictors of device choice.

The surgeon model factors include the provider characteristics that are available or derived from the Medicare provider data base and hip fracture claims. The surgeon model factors reflect differences in surgeon’s career stage, experience, professional certification and advancement, practice site influences and implied proficiency from hip fracture case volume. Although surgeons typically make hip fracture device choices without input from patients, hospitals and surgeons are expected to interact regarding the nature of implants available at a given hospital, hence the bidirectional influences between surgeons and hospitals, but not between providers and patients.

The hospital model factors include those characteristics that are known to affect technology adoption and mortality, including type of ownership, case volume and teaching status.

Figure 1.1: Conceptual model of factors that influence device choice for elderly hip fracture treatment



III. Specific aims

Manuscript 1

- Determine the extent of geographic variation in IMN use 2000 through 2002
- Determine which patient characteristics were associated with IMN use among Medicare intertrochanteric hip fracture patients 2000 through 2002

Manuscript 2

- Determine the physician and hospital factors that were associated with the use of IMN devices for intertrochanteric hip fracture treatment in Medicare patients, controlling for patient characteristics, 2000 through 2002

Manuscript 3

- Determine if Medicare intertrochanteric hip fracture patients treated by high-volume surgeons and hospitals had lower inpatient through 90-day mortality than patients of low volume providers, 2000 through 2002

IV. Background

Hip fractures are classified based on the specific location of the fracture, including femoral neck, intertrochanteric, and subtrochanteric fractures. The vast majority of hip fractures are treated surgically[3, 21]. The type of surgery is generally based on the fracture pattern and other patient characteristics. The short term goal of surgical treatment is to stabilize the hip fracture enough to allow for early patient mobilization and ambulation, which aids in fracture healing and helps minimize complications due to bedrest during recovery.

Intertrochanteric hip fractures

Intertrochanteric hip fractures are most often surgically treated with *internal fixation*, which consists of two categories of metal implants: plate-with-screws (plate/screws) or intramedullary nail (IMN) devices[22]. The plate portion of a plate/screws device is surgically affixed along the outside of the femur, and multiple screws cross the proximal femur to anchor it in place. In contrast, IMN devices are surgically positioned inside the central canal of the femur, rather than alongside it, hence the term *intra*medullary. The plate/screws procedures require a longer incision along the lateral aspect of the thigh, whereas the IMN devices are slid into the femoral canal through a smaller incision near the top of the hip. Although uncommon, total hip replacement may be used to treat an intertrochanteric fracture in patients with rheumatoid arthritis, or in cases of local bony pathology, such as pathologic fractures or osteonecrosis [38]. The focus of this project is exclusively on the use of internal fixation devices in the treatment of Medicare intertrochanteric hip fracture patients.

Device Indications

While there is excellent orthopaedic consensus that intertrochanteric hip fractures require surgical stabilization[3], the clinical evidence is unclear as to which device is best utilized under what circumstances, based on patient factors and fracture patterns[22, 26-28, 30, 31, 39]. Methodological flaws are numerous in clinical studies comparing the two device types, making the determination of the optimal device indications difficult[22]. Despite this lack of literature agreement, there is modest evidence that certain uncommon, unstable fracture patterns do worse with plate/screws devices, and may therefore benefit from IMN[40, 41].

Clinical Outcomes

Functional outcomes are comparable among plate/screws and IMN patients[22, 29, 32]. While postoperative mortality rates associated with the IMN and plate/screws procedures appear similar, the literature on complication rates and revision rates is varied[22, 26-28, 31, 39, 42]. The most consistent problem that is unique to IMN implants for intertrochanteric fracture treatment continues to be femur fractures distal to the device, both during surgery and many months following surgery[22, 23, 39, 41]. Studies comparing the two devices often involved orthopaedic resident cases, and commonly did not control for the general level of surgical experience among treating surgeons, nor specific experience with the IMN devices[22, 25, 27].

V. Literature review

Model factors:

Patients

Age, sex and race

Hip fracture rates increase with age across all race and sex categories. Age-specific hip fracture rates are highest for white women, with their rates of hip fracture increasing exponentially after the age of 70[43-45]. The second highest rates are for black women[45, 46]. Differences by race in the rates of hip fracture are believed to generally reflect the higher bone density among blacks compared to whites[47]. Despite these fracture rate differences by race, we are not aware of any studies that have compared device use based on bone density alone.

Comorbidities

The number and type of comorbidities at the time of hospital admission for hip fracture is significantly and positively associated with mortality, both during hospitalization and within one year following hip fracture[7, 9, 48, 49]. The presence of dementia or delirium at the time of hip fracture is associated with poorer outcomes and higher mortality[7, 48]. We adjusted for the number and type of comorbidities using an adapted Charlson comorbidity index[50, 51]. Although we assumed that surgeons consider comorbidity severity in their surgical planning, no studies indicate that device selection for intertrochanteric hip fracture treatment is based on comorbidities.

Pre-fracture residence and Medicaid-administered assistance

Pre-fracture disability is highly correlated with poorer functional outcomes following hip fracture, resulting in a higher likelihood of needing long term nursing home placement[52-54]. We used pre-fracture nursing home residence as a marker for poor functional status, cognitive impairment or frailty. This nursing home residence indicator likely underestimated the true prevalence of varying degrees of functional limitation, capturing only those with the poorest functional condition, greatest degree of mental impairment, or a combination thereof. However, the addition of a nursing home indicator identified the very frail elderly patients, and provided valuable additional information on mortality risk that could not be obtained from a Charlson comorbidity score alone. Additionally, residence prior to fracture allowed for the determination of whether a particular device was associated with a patient coming from a nursing home. Plate/screws devices may be used more often when patients are expected to place low demands on their implants, being either marginal or non-ambulators. Based on this premise, we expected higher plate/screws use among nursing home hip fracture patients.

Subtrochanteric fracture

Subtrochanteric fractures are considered unstable, and may therefore benefit from the IMN devices[55, 56].

Surgeons

The physician factors included are those that are known to influence the rate of new technology adoption in health care, or those that are associated with general levels of surgical proficiency. Our model included the following surgeon factors: intertrochanteric fracture case volume, surgeon age as a measure of experience, Board-certification status, degree (MD or DO), specialty and practice type (group, other). Intertrochanteric fracture case volume was calculated directly from the surgeons' claims. The literature currently lacks information on how individual physician factors, such as age and level of experience, relate to surgical procedure choices.

Procedure volume

Studies that examined physician factors relative to resource use and outcomes across multiple surgical specialties showed that higher physician surgical volumes resulted in lower mortality, fewer complications and shorter hospital stays[57-64]. Although relatively small numbers of surgeons were classified as high volume across several studies, those who were performed a disproportionately large numbers of cases[60-62]. The number of surgical cases of a particular condition necessary for a surgeon to qualify as *high volume* varied across studies and cut-points were often arbitrarily determined.

We hypothesized that the greatest increase in IMN use would be among surgeons who performed the largest number of intertrochanteric fracture cases per year. Surgeons who treat a lower volume of intertrochanteric fractures are less economically affected by differences in intertrochanteric procedure payments than are surgeons who do large numbers of intertrochanteric fracture procedures each year for Medicare beneficiaries.

Surgeon experience

In clinical trials of intertrochanteric fracture treatment, the level of surgeon experience in general and the amount of surgical experience with the IMN device was often not controlled for. As an estimate of surgical experience, this series of papers used a calculated surgeon age from the Medicare provider enrollment file, because it was more often populated with sensible values than we found within the medical school graduation year field.

Physician age, Board-certification, practice structure and specialty

One recent study examined IMN use among young surgeons applying for Orthopaedic Board certification[34]. However, we found no other surgical studies that examined the relationship between physician age, years of experience or Board-certification status and device choice. Physician practice structure (group, non-group) and practice location were not included in the models that studied resource use relative to surgery, including orthopaedic surgery[65].

Physician age up to 50 years, more than 10 years of experience, and being Board-certified are associated with higher adoption rates of new procedures[65]. Board-certification is believed to accompany a higher level of attendance at professional seminars, thereby affording greater exposure to new technology and procedures. The maximum adoption rate was estimated to occur when physicians are at approximately 50 years of age, and less than 25 years out of medical training[65]. Physicians in solo practice in non-urban locations adopted the least number of new procedures annually, which was thought to be related to a lower amount of peer exposure to, and support in, the use of new procedures.

Hospitals

For elderly intertrochanteric fracture treatment under Medicare DRGs, additional financial pressure is placed on hospitals by surgeons' use of IMN devices, due to the high cost of IMN implants relative to plate/screws devices. Device costs are rolled into Medicare DRG payments to hospitals, and are not reimbursed separately[66]. We assume that hospitals aim to minimize costs and maximize revenue. Hospital cost containment incentives imposed by Medicare DRGs are in direct contrast to the surgeon income incentives created under Part B within the same payment system. Higher priced implants are thought to be less desirable to hospitals, unless such devices routinely decrease hospital costs in other stay-related variables, such as decreasing operating room times, lowering complication rates or shortening hospital stays.

Teaching status and residents

The orthopaedic literature indicates that the presence of an orthopaedic residency training program is associated with longer hospital lengths of stay and higher readmission rates[59]. Orthopaedic resident involvement in hip fracture cases is associated with higher complication rates among patients with complex fractures[67].

From the technology diffusion literature, teaching hospitals tend to be early adopters of new technology, compared with non-teaching facilities[68]. Patients treated in teaching hospitals may have lower mortality rates following hip fracture surgery when compared with patients treated at non-teaching facilities[69]. Teaching surgeons have a responsibility to provide residents with exposure to a wide range of technology and procedures, some of which may be new. Device industry representatives focus a great deal of attention on teaching facilities to provide residents with experience in the use of their particular brand and type of devices, in hopes that such usage will continue after graduation.

Hospital intertrochanteric procedure volume

Most studies that assessed the relationship between hospital surgical volume and clinical outcomes, such as mortality and complication rates, found that higher hospital and surgeon volumes of a particular procedure were associated with better outcomes and fewer complications[57, 58, 60, 63, 64, 70]. Although hospital surgical volume was included as a predictor in models that assessed adverse event rates, individual surgeon volume had a stronger influence on complication rates and hospital length of stay than hospital factors, both individually and combined[59, 62, 71].

Literature on geographic variation in surgical procedure rates

Table 1.1: Geographic variation in surgical procedure rates across the United States is well documented[3, 34, 72-76]. There is considerable interest in geographic variation in the rates at which elective surgical procedures are performed[72-75, 77]. In orthopaedics, extensive geographic variation has been noted for elective procedures such as hip replacement[78, 79].

Table 1.1: Factors associated with geographic variation in surgical procedure rates, particularly orthopaedic

Author (year)	Title	Procedure type	Population	Data	Findings
Birkmeyer JD, et al. (1998)[73]	Variation profiles of common surgical procedures	Elective and non-elective	Medicare fee-for-service patients, age 65-99 years, enrolled in 1995	Hospital discharge abstracts	Highest geographic variability in surgical rates was among "discretionary" procedures (back surgery, carotid endarterectomy, radical prostatectomy, leg revascularization); lowest for hip fracture repair, colorectal cancer resection and cholecystectomy
Burns RB, et al. (1997)[78]	Variations in the performance of hip fracture procedures	Non-elective	Age 65 or older patients hospitalized with a femoral neck fracture in 3 U.S. cities (n=332)	Medicare 1988-89	Use of hip replacement more common in Houston and Pittsburgh than Minneapolis; highest variability among patients with nondisplaced fractures
Ciol MA, et al. (1996)[80]	An assessment of surgery for spinal stenosis: time trends, geographic variations, complications and reoperations	Elective	Medicare beneficiaries age 65 or older who had surgery for spinal stenosis in 1985 or 1989	Medicare claims	Five-fold variation in surgery rates across U.S. states; overall spinal stenosis surgery rates increased 8-fold; complication rates were substantial
Jaglal SB, et al. (1997)[79]	Temporal trends and geographic variation in surgical treatment of femoral neck fractures	Non-elective	Age 50 or older patients surgically treated for a femoral neck fracture 1981-1992	Ontario hospital discharge abstracts	38-fold variation in total hip arthroplasty and 9-fold in hemiarthroplasty across counties. Hemiarthroplasty more common in women, nursing home and older patients. Authors cited hospitals as source of variation

Weinstein JN, et al. (2006)[74]	United States' trends and regional variations in lumbar spine surgery	Elective	Medicare fee-for-service lumbar discectomy, laminectomy or fusion patients, age 65 or older in 306 hospital referral regions, 1992-2003	Medicare claims and enrollment data	20-fold variation in lumbar fusion rates in 2002-03; 8-fold regional variation in discectomy/laminectomy. Spine procedure rates highly correlated with discectomy rates, but not correlated with per capita supply of surgeons. Marked increase in fusions after approval of new implant
Wennberg J, Gittelsohn, A (1982)[81]	Variations in medical care among small areas	Elective: prostatectomy hysterectomy tonsillectomy cholecystectomy appendectomy herniorrhaphy	Six New England states	Hospital registries for 3 states; vague on other state (or Medicare) sources	Dramatic variation (4-6 fold) in surgical procedure rates, especially procedures with marked disagreement among surgeons about the value of surgery. Physician practice styles considered the strongest influence on wide variation in surgery rates
Anglen JO, Weinstein JN (2008)[34]	Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database	Non-elective	Intertrochanteric hip fracture case information and x-rays submitted by candidate surgeons for Board-certification	American Board of Orthopaedic Surgery Database	Regional variation was substantial. The highest rates of IMN use were by candidates from the South, Southeast, and Southwest, who converted to the new technology faster than those in the Northeast, Northwest, and Midwest

Literature on the association between provider volume and mortality

Table 1.2: There is a positive volume-outcomes relationship for a wide range of surgical procedures across a variety of specialties, such as cardiology and oncology[82, 83]. After adjusting for patient case-mix differences, higher surgeon and hospital procedure volumes are associated with lower mortality rates, fewer perioperative complications, and often shorter hospital stays[82-87]. Orthopaedic volume-outcomes research has focused almost exclusively on elective arthroplasty procedures, where evidence suggests that patients who undergo surgeries by low volume surgeons at low volume hospitals have higher mortality and perioperative complication rates[57, 58, 62-64, 70, 88-90]. The specific mechanisms that account for the observed volume-outcomes benefits remain largely unidentified.

Table 1.2: Orthopaedic studies that examined provider case volume in relation to mortality and complication rates

Author (year)	Title	Surgical procedure(s)	Population	Data	Findings
Hervey SL, et al. (2003)[58]	Provider Volume of Total Knee Arthroplasties and Patient Outcomes in the HCUP-Nationwide Inpatient Sample	Total knee arthroplasty (TKA)	All TKA patients	Hospital discharge abstracts from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample 1997	Surgeon volumes of 15 or more cases/year and hospital volumes of 85 or more cases/year had significantly lower mortality rates than lower volume providers. Length of stay and complication rates did not differ by provider volume.
Katz JN, et al. (2001)[63]	Association between hospital and surgeon procedure volume and outcomes of total hip replacement in the United States Medicare population	Primary total hip replacement (THR) and revision THR	Age 65 or older, non-managed care enrollees	Medicare claims: July 1995 through June 1996	*Hospitals*: THR of >100 cases/year was associated with a lower risk of death than in low THR volume hospitals (<10/year). *Surgeons*: THR of > 50 cases/year had a lower risk of dislocation than low volume surgeons. Revision THR by high volume surgeon (>10/year) had lower mortality rates than patients of low volume (<3 revisions/year) surgeons
Katz JN, et al. (2004)[64]	Association between hospital and surgeon procedure volume and the outcomes of total knee replacement	Primary total knee replacement	Age 65 or older, non-managed care enrollees	Medicare claims 1/1/00-8/31/00	Patients treated at high TKA-volume hospitals (>200 cases/year) had a lower risk of mortality and perioperative complications. Patients of surgeons who performed more than 50 TKA per year also had lower risks of any adverse outcomes than among patients of low volume (<12 TKA/year) surgeons

Kreder HJ, et al. (1997)[57]	Relationship between the volume of total hip replacements performed by providers and the rates of postoperative complications in the state of Washington	Elective hip replacement	Age 18 or older	Statewide hospital discharge registry 1988 - 1991.	Patients managed by low-volume surgeons (< 2 hip replacements per year) had higher mortality rates, more infections, higher rates of revision operations, and more serious complications during the index hospitalization.
Lavernia CJ, Guzman JF (1995)[89]	Relationship of surgical volume to short-term mortality, morbidity, and hospital charges in arthroplasty	Primary and revision THR, TKR	All discharges for THR, TKR	Florida state patient discharge information 1992 (Agency of Health Care Administration)	Patients of surgeons with a low volume of primary cases (< 10) have a significantly higher mortality rate (24%), higher charges and longer hospital stays than high volume surgeons. Similar findings for revision arthroplasties
Lavernia CJ (1998)[90]	Hemiarthroplasty in hip fracture care: effects of surgical volume on short-term outcome	Hemiarthroplasty	All discharges for hemi-arthro-plasty	Florida state patient discharge information 1992 (Agency of Health Care Administration)	After arbitrarily dividing the doctors into three case volume groups (low, medium, high), surgeons with low volumes of arthroplasty cases (<10 /year) had higher lengths of stay and hospital charges when compared with the other two case volume groups
Taylor HD, et al. (1997)[88]	Relationship between mortality rates and hospital patient volume for Medicare patients undergoing major orthopaedic surgery of the hip, knee, spine, and femur	Total hip arthroplasty, partial hip arthroplasty, revision total hip arthroplasty, total knee arthroplasty, and revision total knee arthroplasty	Medicare	Medicare patients 1993-1994 in DRGs 209, 210, 214: in-depth study of DRG 209	Higher-volume hospitals had lower mortality rates, both inpatient and 1 month after discharge for each of the DRGs studied and for each of the individual procedures within DRG 209

Other factors that impact device selection: payment and technology

Reimbursement and practice patterns

A significant body of literature demonstrates how physician treatment decisions are affected by reductions in reimbursement, including changing office visit frequency, changing the volume of tests ordered, increasing service intensity (amount of work, time or treatment rendered per encounter or surgery), and altering the quantity of procedures and surgical services performed[91-98]. Physician payment reductions by one payer in a multi-payer environment may result in volume changes in procedures regardless of payer[99]. Situations of clinical uncertainty as to the best procedure for a given patient situation afford better opportunities for physicians to make treatment decisions based on non-patient factors[98].

Technology diffusion

Health technology diffusion and adoption rates are known to vary by geographic area[68, 100]. The practice of medicine is strongly influenced by local professional opinions and standards[100]. The decision by surgeons to utilize a new implant depends not only on individual surgeon factors, but also on the local professional climate within a hospital, area hospitals and physician groups, industry influences and training[101]. Prior adoption of newer technology by another surgeon in the same hospital has been shown to expedite the adoption by other surgeons in the same hospital[102]. Individual surgeon adoption decisions are also influenced by their perceived need for a new device to treat a particular condition, their understanding of the indications for use of the device, clinical outcome studies that apply to their patient population, technical considerations for the use of a new device and reimbursement[101, 103].

VI. Data and study designs

Data and case selection

The focus of this project was the treatment of simple hip fractures in elderly individuals, most of which result from falls from a standing height[104].

Medicare claims and enrollment data from March 1, 2000, through December 31, 2002, were used to identify Parts A- and B-enrolled, non-managed care Medicare beneficiaries, age 65 or older, who underwent an inpatient surgery to treat an intertrochanteric femur fracture using either an IMN or a plate/screws device. We used 2000-2002 as the study period because IMN devices were in widespread use in the United States, and did not undergo design modifications from 1998 through 2002.

Patient data were obtained from the 100% Medicare Provider Analysis and Review (MedPAR) hospital claim files, the Medicare Carrier (physician) claim files and the Denominator (enrollment) files for 2000 through 2002. Surgeon and hospital characteristics were determined from the Medicare Physician Identification and Eligibility Registry (MPIER) file and the Medicare Provider of Services (POS) facility file, and merged with the claims using the unique Medicare provider numbers.

Surgery dates were matched by patient identification numbers across the hospital and physician claims within a plus or minus 7 day time window[105]. For patients with more than one intertrochanteric hip fracture during the study period, only the first surgical claim was retained. Since our interest was in index, low-energy elderly hip fractures, we excluded patients whose hospital claim indicated surgery for complications or revisions of previous hip surgery, metastatic or associated cancers, infection, bilateral fractures or high-energy trauma. Additional case selection details are provided in Appendix A[106].

The first manuscript used January 1, 2000 through December 31, 2002 hip surgery claims, while the second and third manuscripts limited cases to a 34-month claim file from March 1, 2000 to December 31, 2002, to allow for a nursing facility Carrier claim look-back.

The study was reviewed by the University of Minnesota Institutional Review Board and determined to be exempt because existing data that did not allow for direct patient identification were used. Consistent with CMS' policy, cell sizes less than 11 are not reported for neither patients nor physicians in this series of papers.

Variables

The patient, surgeon and hospital variables used in the analysis are identified in Tables 1.3, 1.4 and 1.5 respectively.

Table 1.3: Patient model factors

Description	Type	Specification	Source
Age (years)	categorical (3 or 6 levels)	0=65-69* or 0=65-74* 1=70-74 1=75-84 2=75-79 2=85+ 3=80-84 4=85-89 5=90+	Denominator and Carrier files: calculated age on the date of surgery by subtracting date of birth (Denominator) from the date of surgery (Carrier). Kept age 65+ on date of surgery
Sex	dichotomous	0=Female* 1=Male	Denominator file
Race	dichotomous	White* Black Other	2 indicator variables. Other = all other identified races (excludes race=*unknown*)
Adapted Charlson comorbidity score	categorical	0*, 1, 2, 3+	Dartmouth-Manitoba adaptation of the Charlson comorbidity score[50, 51]
Subtrochanteric fracture code	dichotomous	No* Yes	Yes=presence of either ICD-9 code 820.22 or 820.32 on either the hospital or surgeon's claim
Pre-fracture residence and Medicaid-administered assistance status	categorical	0*= Non-nursing home, Medicare-only 1= Nursing home, Medicare-only 2= Non-nursing home with Medicaid-administered assistance 3= Nursing home with Medicaid-administered assistance	4-level categorical variable constructed from pre-fracture nursing home residence cross-classified with Medicaid administered assistance status

*reference group

Table 1.4: Surgeon model factors

Description	Type	Specification	Source
Age (years)	categorical	1= less than 35 2= 35-39 3= 40-44 4= 45-49* 5= 50-54 6= 55-59 7= 60-64 8= 65 or older	Physician's MPIER date of birth was used to calculate surgeon age as of 12/31/2001
Practice structure	dichotomous	0= Group* 1= Solo	MPIER Carrier Specialty=70: group practice Group Practice Code or
Professional degree	dichotomous	0= MD* 1= DO	MPIER Credentials Code: two fields: Verified with Physician Status Code
Surgical specialty	dichotomous	0= Orthopaedics* 1= Other	Primary or secondary specialty=20 (Orthopedic surgery)
Orthopaedic Board-certification	dichotomous	0= Yes* 1= No	If Primary or secondary specialty=20, the corresponding Board certification field was YES for any PIN, per provider UPIN (unique provider ID number)
Intertrochanteric fracture volume, per year	categorical	Quartiles: 1-4 cases 5-10 11-17 18 or more*	Total Medicare IT fracture case volume by UPIN, per year
Number of surgical hospitals per surgeon	dichotomous	1*, 2, 3, or 4+	Count of unique hospital provider numbers per surgeon UPIN from the Carrier claims

* indicates reference level. All factors determined from the MPIER file unless otherwise stated.

Table 1.5: Hospital model factors

Variable	Description	Specification	Source
Volume of intertrochanteric hip fracture procedures	Total number of Medicare intertrochanteric hip fracture surgeries treated with IMN or plate/screws over 34 months, 3/1/2000 – 12/31/2002	Quartiles: 1-17 cases 18-41 42-78 79 or more*	Calculated using the facility provider number. If facility provider numbers changed during study, volume was determined using the most recent provider number
Profit status	Non-profit*, for-profit, government	2 indicator variables	Medicare Provider of Services (POS) file
Teaching status	Facility-level determination of teaching status, plus identification of cases indicating orthopaedic resident cases (orthopaedic training programs)	Non-teaching* or teaching without any resident case(s) or teaching with 1+ resident case(s)	POS for hospital teaching status and –GC modifier on surgeon's Carrier claim indicating resident involvement

Study designs and analyses

Manuscript 1

The dichotomous outcome of interest was receipt of an intramedullary nail for an intertrochanteric hip fracture treated with internal fixation between 2000 and 2002. Categorical patient demographic variables are reported as the number and percent. We used multiple logistic regression analysis[107, 108] to model the associations of IMN use with state and year, with and without adjustment for the patient factors of age, sex, race, Charlson score, Medicaid-administered assistance with Medicare premiums, and subtrochanteric fracture. The odds ratios of receiving an intramedullary nail are reported with the 95% confidence intervals, Wald chi-square values, and p values. Likelihood ratio chi-square tests were used to compare models. To further examine geographic variation in intramedullary nail use, the unadjusted and adjusted state rates of IMN use compared with plate/screws use were determined for each year with use of the individual predicted probabilities of IMN use generated from logistic regression models (state versus state plus adjustors) and aggregating within states. There were no differences between the adjusted and unadjusted state rates of intramedullary nail use per 100 fractures to two significant figures; therefore, we report only the adjusted rates. Spearman rank correlation was used to compare states' relative IMN use across study years.

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We used generalized linear mixed models with fixed and random effects to model the association between surgeon and hospital factors, and the dichotomous outcome of device choice (IMN or plate/screws), while controlling for patient factors. These models can account for the correlated nature of the data, nonlinear associations between the independent predictors and the device choice outcome, and the imperfect nesting of surgeons within hospitals[109, 110]. Patients in this study were perfectly nested within surgeons but surgeons often operated at several hospitals, with just over half of surgeons operating at only one hospital during the study period. Since generalized linear models are likelihood based, the standard likelihood ratio tests were used to compare nested models[109]. Non-nested models were compared using information criteria, which penalizes the log likelihood for the number of model parameters (Akaike Information Criterion, AIC) or subjects (Bayesian Information Criterion, BIC), with smaller values indicating better fit of the model to the data[109].

Three types of models were considered: fixed (means) without random effects, random hospital intercepts, and random surgeon intercepts. We examined four groups of predictors, each with and without random surgeon or hospital intercepts, for a total of 12 models, including an intercept-only model, patient factors with year, patient and surgeon factors with year, and patient, surgeon and hospital factors with year, for which AIC and BIC model fit estimates are reported. Analyses were conducted using the SAS statistical program, NLMIXED, version 9.1 for Windows (SAS Institute, Inc., Cary, NC, USA)[111]. Coefficient estimates, standard errors, odds ratios (OR) and 95% confidence intervals (CI) for the odds ratios are reported for the surgeon, hospital and year predictors of the best fitting model only; odds ratios only are reported for model comparisons. Descriptive statistics are reported as percent, mean or median.

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All analyses were conducted using the SAS statistical program, version 9.1 for Windows (SAS Institute, Inc., Cary, NC, USA)[111]. Unadjusted mortality is reported as the number and percent of deaths among Medicare intertrochanteric femur fracture patients treated with internal fixation between March 1, 2000 and December 31, 2002, using the total number of internal fixation cases as the denominator. Categorical variables are reported as frequency and percent of internal fixation cases. Continuous variables are reported as mean or median values then analyzed as categorical variables in the regression models for ease of comparison. Initial bivariate associations between categorical predictor variables and mortality were examined using chi-square tests. Homogeneity of the odds ratios across multilevel categorical predictors were assessed using chi-square tests.

Separate multiple logistic regression models were used to examine the association between device, surgeon and hospital volume with inpatient, 30, 60 and 90-day mortality, after controlling for other patient, surgeon and hospital factors. The unit of analysis was individual patients. Fixed effects regression analyses using generalized estimating equations (GEE) were used to account for the similarities among patients treated within the same hospital. The GEE models assume that outcomes for patients treated within the same hospital are correlated, but independent across hospitals[107]. Models were initially tested by calendar year to assess time trends then pooled for the final analyses due to consistency of our findings over time. Results are reported as the odds ratios of mortality for patients with a specific predictor value compared with the reference group of that factor, after controlling for all other model factors. The highest pooled case volume quartiles for surgeons (18 or more) and hospitals (79 or more) served as the volume reference groups, and the oldest group of surgeons (age 50 or older) as the surgeon's age reference group for regression analyses. Tests for linear trend in mortality across the surgeon and hospital volume levels were performed.

The final regression models included hospital and surgeon intertrochanteric fracture volume, surgeon age, the type of hospital ownership and hospital teaching status as predictors of mortality, controlling for patients' age, sex, race, adapted Charlson comorbidity score, subtrochanteric fracture, pre-fracture nursing home residence, Medicaid-administered assistance status, device and year (2000-02).

CHAPTER 2: MANUSCRIPT 1

GEOGRAPHIC VARIATION IN DEVICE USE FOR INTERTROCHANTERIC HIP FRACTURES

I. Abstract

Background: Hip fractures in the elderly are a common and costly problem, with intertrochanteric fractures accounting for almost half of these fractures. Most intertrochanteric fractures are treated with either a plate-with-screws device or an intramedullary nail device. We assessed the degree of geographic variation in use of intramedullary nailing for intertrochanteric femoral fractures among Medicare beneficiaries between 2000 and 2002. **Methods**: Medicare 100% files (hospital and physician claims, and enrollment) for 2000 through 2002 were used to identify beneficiaries, sixty-five years of age or older, who had undergone inpatient surgery for the treatment of an intertrochanteric femoral fracture with a plate-and-screw device or an intramedullary nail. We used multiple logistic regression analysis to model the use of an intramedullary nail (as opposed to a plate-and-screw device) by state and year, after adjusting for patient age, sex, race, subtrochanteric fracture, comorbidities, and Medicaid-administered assistance. The odds ratios of receiving an intramedullary nail device are reported. The adjusted state rates of intramedullary nailing per 100 Medicare patients with an intertrochanteric fracture are reported for 2000 through 2002. **Results**: In this study, 212,821 claims for operations to treat patients with an intertrochanteric fracture from 2000 through 2002 met the inclusion criteria. There was considerable geographic variation in intramedullary nail use by state across all years. The mean adjusted intramedullary nailing rate per 100 Medicare patients with an intertrochanteric fracture increased nationally from 7.84 in 2000 to 16.98 in 2002. In 2000, surgeons in sixteen states used an intramedullary nail in fewer than one of every twenty Medicare patients with an intertrochanteric fracture. By 2002, surgeons in only two states used an intramedullary nail in fewer than one of every twenty patients with an intertrochanteric

fracture, and in eight states they used an intramedullary nail in more than one of every four patients with an intertrochanteric fracture. **Conclusions**: There was substantial geographic variation in the use of intramedullary nailing by state from 2000 through 2002 that was largely not explained by patient-related factors.

II. Background

Hip fractures in elderly patients are a common and expensive problem, with an estimated incidence among United States Medicare beneficiaries of more than 266,000 fractures annually and costs estimated at $2.9 billion per year[1, 3, 112]. Intertrochanteric femoral fractures account for approximately 47% of hip fractures in older Americans[18, 20, 21]. The vast majority of these fractures are treated with one of two types of implants: plate-with-screws (plate/screws) devices or intramedullary nail (IMN) devices. In rare instances, such as in patients with osteonecrosis, rheumatoid arthritis, or a pathologic fracture, total hip replacement is used to treat an intertrochanteric fracture[38].

Geographic variation in surgical procedure rates across the United States is well documented[3, 72-76]. There is considerable interest in the geographic variation in the rates at which elective surgical procedures are performed[72-75, 77]. Our study differs in that we focused our analysis on the rates at which alternative procedures are performed for surgical treatment of a hip fracture.

Although intramedullary nails have been compared with plate/screws devices in a number of randomized clinical trials, no data support the routine use of intramedullary nails in the treatment of stable pertrochanteric fractures, which account for more than two-thirds of intertrochanteric hip fractures among the elderly[22, 25-28, 31, 32, 39, 40, 113-115]. The findings in orthopaedic randomized trials do not support the use of plate/screws devices for a limited number of pertrochanteric fractures, primarily those with an unstable pattern, including reverse oblique and transverse intertrochanteric fractures[40, 116-118]. There is modest support in the literature for the use of intramedullary nailing to treat intertrochanteric fractures with subtrochanteric extension, but the quality of the research supporting this trend is less robust and the results may be surgeon and technique-dependent[23, 24, 55, 56]. A clinical advantage of intramedullary nail fixation for other, more common pertrochanteric fracture patterns has not been demonstrated in well-designed, sufficiently powered clinical trials[22, 30, 32]. Despite design modifications, intramedullary nail devices continue to be associated with a small but persistent risk of iatrogenic femoral shaft fracture both intraoperatively and for many months postoperatively[22, 23, 41].

In light of insignificant differences in functional and clinical outcomes across device categories[22, 25-28, 39], surgeons use professional discretion to choose implants for the treatment of intertrochanteric fractures in elderly patients. In the absence of clearly superior outcomes with intramedullary nailing for most intertrochanteric fractures, it is plausible that surgeons select the device, at least in part, on the basis of nonpatient factors, such as local or group practice norms, surgical experience, degree of technical difficulty, and level of financial reimbursement.

In this study, we assessed the degree of geographic variation in the use of intramedullary nails for intertrochanteric femoral fractures in United States Medicare beneficiaries. Although geographic variation in the use of total hip replacement for femoral neck fractures has previously been examined[78], to our knowledge this is the first study to assess the extent of geographic variation in the use of intramedullary nails. We hypothesized that this geographic variation is significant and that it persists after adjustment for patient factors. We selected 2000 through 2002 as the study period because intramedullary nail devices were in widespread use by that time and had not undergone major design modifications since 1998.

III. Methods

Medicare claims and enrollment data from January 1, 2000, through December 31, 2002, were used to identify all United States Medicare beneficiaries who had undergone inpatient surgery for the treatment of an intertrochanteric femoral fracture with either a plate/screws or an intramedullary nail device. Specifically, we used the Medicare Provider Analysis and Review (MedPAR, Part A) 100% files, the Medicare Carrier (Part B) files, and the beneficiary enrollment (Denominator) files for 2000 through 2002.

This study was reviewed by the University of Minnesota Institutional Review Board and determined to be exempt under Category 4, because existing data that do not allow direct patient identification were used.

Sample

Using diagnosis and procedure codes contained in the 100% MedPAR hospitalization files, we identified Medicare beneficiaries who had undergone inpatient surgery for treatment of an intertrochanteric femoral fracture between January 1, 2000, and December 31, 2002. From the Medicare Carrier files, we identified surgeon claims that indicated whether an intramedullary nail or a plate/screws device had been used for treatment of the intertrochanteric fracture, and we kept only the first surgeon claim per patient for a surgical procedure to treat a hip fracture in the period of 2000 through 2002. Data files were merged by a unique patient identifier.

Cases were included if there was a specific ICD-9 (International Classification of Diseases, Ninth Revision) diagnosis code of pertrochanteric femoral fracture (820.2x to 820.3x) on either the hospital or physician claim for a particular surgical procedure and the patient was at least sixty-five years of age on the date of the surgery. Surgery dates were considered to match if the dates for procedures with the appropriate diagnosis codes on the hospital and physician bills were within seven days of each other. We included only patients who were enrolled in both Part A and Part B Medicare during their hospital admission.

Our interest was in the treatment of simple hip fractures, most of which result from falls from a standing height in elderly individuals. We therefore excluded patients who were less than sixty-five years of age on the date of the surgery and those whose hospital claims indicated complications or revisions of previous hip surgery, infection, associated cancers, or high-energy trauma. Patients enrolled in managed care at any point in the period of 2000 through 2002 were excluded, since managed care claims are not contained in the Medicare utilization files. Appendix A details our case selection criteria[106].

Variables

We modeled intramedullary nail use as a function of state and year (2000 through 2002). The state where each hip procedure was performed was determined by the provider state code in the Carrier file, which attributed hip fracture operations that were performed outside of a beneficiary's state of residence to the state of the operating surgeon. We included procedures performed by surgeons within the fifty United States and the District of Columbia. The year was the year of the surgery as billed on the surgeon's procedure claim.

The covariates included patient age, sex, race, subtrochanteric fracture, Charlson comorbidity score, and state Medicaid-administered assistance status. The covariates were selected as standard demographic adjustors and to account for differences in subtrochanteric fracture rates across states[21, 48, 63, 119]. Age was categorized into five-year groups, with one combined category for patients who were ninety years of age or older. We categorized race as white, black, or other (all other races) as listed in the enrollment file race categories to account for differences in bone density by race[120]. Comorbidity scores were calculated with use of an adaptation of the Charlson comorbidity score on the basis of information in the hospital claim for the hip surgery of interest[50, 51]. Comorbidity scores were categorized as 0, 1, 2, or ≥3. Subtrochanteric fractures were identified if a specific ICD-9 diagnosis code for subtrochanteric fracture (820.22 or 820.32) was present on either the physician or the hospital claim for the surgery of interest. In an effort to control for socioeconomic status, patients who received financial assistance with Medicare premiums under state Medicaid-administered programs were identified from the beneficiary enrollment file with use of the "state buy-in" variable. Additional surgeon and hospital predictors were not included.

Statistical Analysis

The dichotomous outcome of interest was receipt of an intramedullary nail for an intertrochanteric hip fracture treated with internal fixation between 2000 and 2002. Categorical patient demographic variables are reported as the number and percent. We used multiple logistic regression analysis[107, 108] to model the associations of intramedullary nail use with state and year, with and without adjustment for the patient factors of age, sex, race, Charlson score, Medicaid-administered assistance with Medicare premiums, and subtrochanteric fracture. The odds ratios of receiving an intramedullary nail are reported with the 95% confidence intervals, Wald chi-square values, and p-values. Likelihood ratio chi-square tests were used to compare models. To further examine geographic variation in intramedullary nail use, the unadjusted and adjusted state rates of intramedullary nail use compared with plate/screws use were determined for each year with use of the individual predicted probabilities of intramedullary nail use generated from logistic regression models (state versus (state plus adjustors)) and aggregating within states. There were no differences between the adjusted and unadjusted state rates of intramedullary nail use per 100 fractures to two significant figures; therefore, we report only the adjusted rates. Spearman rank correlation was used to compare states' relative intramedullary nail use across study years.

IV. Results

Demographics

Of the 216,927 Medicare claims for operations performed to treat an intertrochanteric femoral fracture from 2000 through 2002 that met the inclusion criteria, 212,821 (98.1%) matched, within the desired time window, with regard to the dates on the hospital and physician bills. Patient demographics were highly consistent across study years (Table 2.1). The average patient age was 83.6 years (range, sixty-five to 109 years); 77.1% of the patients were female. The majority of patients (94.6%) were white, and the majority (80.9%) did not receive Medicaid-administered assistance with their Medicare premiums. Nearly half (49.0%) of all patients had a modified Charlson score of 0 (no comorbidities); 35.6% had a comorbidity score of 1. Subtrochanteric fractures accounted for 10.05% of the cases in 2000 and 10.96% in 2002. The subtrochanteric fracture rates in the different states ranged from 4.8% to 16.5% during the study period.

Geographic Variation

The maps in Figures 2.1 and 2.2 show the adjusted state rates of intramedullary nail use per 100 Medicare patients with an intertrochanteric fracture treated with internal fixation in 2000 and 2002. There was considerable geographic variation in intramedullary nail use by state across all years. There were no differences to two significant figures between the adjusted and unadjusted state rates of intramedullary nail use in any study year. The mean adjusted rate of intramedullary nail use per 100 Medicare patients with an intertrochanteric fracture treated with internal fixation increased nationally from 7.84 in 2000 (range by state, 1.96 to 27.63) to 10.88 in 2001 (range, 1.76 to 39.39), to 16.98 in 2002 (range, 2.39 to 40.13). In 2000, surgeons in sixteen states used an intramedullary nail in fewer than one of every twenty Medicare patients with an intertrochanteric fracture. By 2002, only in Alaska and Maine did surgeons use an intramedullary nail in fewer than one in twenty Medicare patients with an intertrochanteric fracture. In 2000, only West Virginia surgeons used an intramedullary nail in more than one of every four Medicare patients with an intertrochanteric fracture, yet by 2002 surgeons in eight states (Arizona, Florida, Mississippi, Montana, Nevada, South Carolina, Utah, and West Virginia) used an intramedullary nail in at least one of four Medicare patients with an intertrochanteric fracture. Surgeons' use of intramedullary nails in West Virginia far exceeded that in all other states in every year, with a rate of 27.63 per 100 patients treated with internal fixation in 2000 and 40.13 per 100 in 2002. Surgeons in Oklahoma more than quadrupled their rate of intramedullary nail use in the treatment of intertrochanteric fractures between 2001 and 2002, from 5.37% to 22.71%. States' 2001 and 2002 relative intramedullary nail use (ranks) were positively and significantly correlated with states' intramedullary nail use levels in 2000 (2000 compared with 2001, rho = 0.858, $p < 0.0001$; 2000 compared with 2002, rho = 0.752, $p < 0.0001$).

The tables in Appendices B and C show the adjusted odds ratios of receiving an intramedullary nail by state, compared with Wyoming, for Medicare patients with an intertrochanteric fracture in 2000 and 2002. Although nearly surrounded by states with high use of intramedullary nails, Wyoming was chosen as the reference state because its rate of intramedullary nail use was near the national average across all three study years (Table 2.2). Within each study year, the adjusted odds ratio ranks by state were highly correlated (2000, rho = 0.991; 2002, rho = 0.995; ranks not shown). The 2002 adjusted odds of patients receiving an intramedullary nail as opposed to a plate/screws device in West Virginia were 6.32 times greater than that in Wyoming (see Appendix C). Following West Virginia, the Mountain and Southeastern states showed the highest levels of intramedullary nail use. Seven of ten states with the highest intramedullary nail use were located in just two of nine Census Divisions: Mountain (Arizona, Montana, Nevada, and Utah) and South Atlantic (Florida, South Carolina, and West Virginia), and this pattern was consistent over time.

Patient Factors and Intramedullary Nail Use

The patterns seen on the maps (Figures 2.1 and 2.2) were confirmed by multiple logistic regression analysis, which showed state to be significantly associated with intramedullary nail use (chi-square = 4436.65, 50 degrees of freedom, $p < 0.0001$, all years), even after adjustment for time and patient factors (Table 2.3). The adjusted odds ratio of receiving an intramedullary nail rather than a plate/screws device for treatment of an intertrochanteric femoral fracture in 2002 was more than double that in 2000 (odds ratio = 2.49, 95% confidence interval = 2.404 to 2.578, $p < 0.0001$). There was a nonsignificant trend of intramedullary nail use decreasing as patient age increased. Men were more likely to receive an intramedullary nail than were women, despite equivalent rates of subtrochanteric fracture for the two genders. Patients whose race was identified as *black* in the enrollment files were nearly 14% more likely to receive an intramedullary nail than were individuals listed as *white* during the three-year period (odds ratio = 1.138, 95% confidence interval = 1.054 to 1.228, $p = 0.001$), even after adjustment for state. Patients who received Medicaid-administered assistance with Medicare premiums were 6.1% more likely to receive an intramedullary nail device than were patients who did not receive such assistance. Adjusting for patient factors significantly improved the model fit (chi-square = 8176.67, 13 degrees of freedom, $p < 0.0001$).

Subtrochanteric fractures were significantly associated with intramedullary nail use (odds ratio = 5.018, 95% confidence interval = 4.854 to 5.187, $p < 0.0001$). With the exception of Nevada, states with the highest odds ratios for intramedullary nail use did not consistently have higher-than-average rates of subtrochanteric fracture. Of patients identified as having a subtrochanteric fracture, fewer than half received an intramedullary nail device in any year (range, 24.0% in 2000 to 43.2% in 2002).

V. Discussion

We found substantial geographic variation, by state, in the rate of intramedullary nail use for Medicare patients with an intertrochanteric fracture from 2000 through 2002 that was not explained by patient factors. The notably high rates of intramedullary nail use in the Mountain and Southeastern states from 2000 through 2002 were not explained by patient factors in this study. Our findings demonstrate that use of an intramedullary nail for the treatment of an intertrochanteric femoral fracture in an elderly patient is strongly associated with geographic location and that these surgeon practice patterns persisted over time.

As expected, there was a strong association between subtrochanteric fractures and intramedullary nail use, as clinical evidence modestly favors the use of intramedullary nails for these unstable fractures[56, 117].

The minimally higher adjusted odds ratio for intramedullary nail use in men compared with women was unexpected given the load-sharing properties of intramedullary nails and the likelihood of suboptimal bone density in women. The finding of higher intramedullary nail use in patients whose race was listed as *black* is inconsistent with the hypothesized need for intramedullary nailing due to lower bone density, since blacks as a group have the highest bone density and lowest hip fracture rates among the races[44, 120]. We are unable to explain the differences that we noted in intramedullary nail use by race, gender, and Medicaid-administered assistance status on the basis of any plausible differences in clinical factors among these patients; therefore, we assume that other, nonpatient factors are responsible for the observed differences. We acknowledge that patient comorbidities, although widely utilized in similar orthopaedic studies, are underestimated when derived from claims from an index admission alone, and we also acknowledge that the modified Charlson score was designed to predict mortality, not device selection[50, 51, 121].

Medicare pays surgeons at different rates according to the relative value units (RVU) designation for operations for intertrochanteric fractures (excluding arthroplasty), with reimbursement depending on the specific fracture treatment selected (plate/screws device or intramedullary nail). In 2002, as calculated from the United States Federal Register, surgeons who used the newer intramedullary nail devices were reimbursed an average of $272 (range, $233 to $328) more per surgical procedure than surgeons who utilized a plate/screws device[122]. In contrast, Medicare pays hospitals a fixed rate per discharge for inpatient care, based on Diagnosis Related Group (DRG) payment categories. Hospitals are reimbursed for both intramedullary nail and plate/screws hip procedures under the same DRG (210 or 211), which are differentiated by the presence or absence of a complicating patient condition, not the fracture treatment method[123]. Medicare DRG payments do not explicitly reimburse hospitals for orthopaedic implants[66], and acquisition costs for the intramedullary nail devices are generally higher than those for plate/screws devices. Thus, hospitals and surgeons have competing payment incentives under the standard economic assumptions that physicians want to maximize their income and hospitals aim to minimize costs.

A lack of consensus among surgeons regarding the optimal treatment for a particular patient situation is a well-known factor in the variation in surgical procedure rates[3, 73]. In the case of hip fractures, in which the fracture volume and therefore the fracture procedure rates are not under the control of the surgeon, surgical variation may play out in terms of the treatments chosen for a particular condition.

An additional source of variation in hip fracture procedures is each surgeon's rate of adoption of new technology (in this case, intramedullary nail devices). Health technology diffusion and adoption rates are known to vary by geographic area[68, 100]. In analyses not specific to hip fracture implants, the technology diffusion rate for orthopaedic implants has been estimated to be somewhere between that of nonimplantable devices (fast) and pharmaceuticals (slow)[103].

To examine the expected versus the observed level of intramedullary nail use in elderly Medicare beneficiaries, we used evidence-based estimates to determine the percentage of intertrochanteric fractures for which the use of a plate/screws device is not recommended and thus an intramedullary nail may be indicated. On the basis of recent orthopaedic clinical outcomes studies[26, 40, 116] and the Medicare data in the present study, we estimated the expected level of intramedullary nail use to be in the range of 14.5% to 26.9% of all elderly patients with a pertrochanteric fracture, accounting for unstable intertrochanteric fractures and a trend in the literature in support of the use of intramedullary nails for subtrochanteric fractures. Specifically, unstable AO/OTA 31-A3 fractures account for 4.4% to 15.9% of intertrochanteric fractures[26, 40, 116], and subtrochanteric fractures in the present study accounted for nearly 11.0% of cases (Table 2.1). We found that, in eight states in 2002, an intramedullary nail was used in more than one of every four Medicare patients with an intertrochanteric fracture, with West Virginia surgeons using an intramedullary nail in 40.13 of every 100 Medicare patients with an intertrochanteric fracture. We are unable to explain the high rate of intramedullary nail use in West Virginia on the basis of patient factors alone.

A strength of this study is that we used a national dataset that contains close to 100% of the elderly not enrolled in managed care in the United States over a three-year period. We specifically excluded cases, such as those with pathologic fracture or a high-energy injury, in which intramedullary nailing has a theoretical benefit, which made our analysis conservative.

Several study limitations must be considered. Fracture patterns are not distinguishable with use of claims alone; therefore, the exact percentages of unstable pertrochanteric and intertrochanteric fractures in each state cannot be determined. Current outcomes data suggest that patients with specific uncommon, unstable fracture patterns have fewer implant-related complications when an intramedullary nail is used than when a plate/screws device is used[116]. Thus, an increased percentage of unstable fracture patterns in some areas may account for a portion of the observed increase in intramedullary nail use. However, we noted that the coding of subtrochanteric fractures, which are typically considered to be unstable, was consistent over time and that states with the highest rates of intramedullary nail use were not those with the highest subtrochanteric fracture rates. Additionally, our analyses utilized patient claim information, procedure year, and the surgeon's state as predictors of device choice, without inclusion of other surgeon or hospital factors.

This study showed extensive geographic variation in the use of differentially reimbursed hip fracture procedures for the treatment of intertrochanteric fractures in Medicare beneficiaries and that this variation persisted after adjustment for patient factors. While rates of adoption of new technologies undoubtedly differ among surgeons, we were unable to explain the substantial geographic variation in intramedullary nail use over time on the basis of patient factors alone, suggesting that nonpatient factors are responsible for the significant variation that was noted.

Table 2.1: Characteristics of Medicare beneficiaries* treated for an intertrochanteric hip fracture from 2000 through 2002

Patient Characteristics Total patients= 212,821	**2000** n=72,676 (34.15%) number (%)	**2001** n=71,434 (33.57%) number (%)	**2002** n=68,711 (32.29%) number (%)
Age (years)			
65-69	2,945 (4.05)	2,894 (4.05)	2,938 (4.28)
70-74	5,903 (8.12)	5,770 (8.08)	5,793 (8.43)
75-79	11,525 (15.86)	11,209 (15.69)	10,663 (15.52)
80-84	17,180 (23.64)	17,100 (23.94)	16,205 (23.58)
85-89	18,821 (25.90)	18,439 (25.81)	17,904 (26.06)
90+	16,302 (22.43)	16,022 (22.43)	15,208 (22.13)
Sex			
Female	56,410 (77.62)	55,068 (77.09)	52,643 (76.62)
Male	16,266 (22.38)	16,366 (22.91)	16,068 (23.38)
Race			
White	68,918 (94.83)	67,553 (94.57)	64,807(94.32)
Black	2,287 (3.15)	2,260 (3.16)	2,185 (3.18)
Other	1,471 (2.02)	1,621 (2.27)	1,719 (2.50)
Charlson comorbidity score			
0	36,384 (50.06)	35,030 (49.04)	32,841 (47.80)
1	25,614 (35.24)	25,378 (35.53)	24,826 (36.13)
2	7,876 (10.84)	8,100 (11.34)	8,128 (11.83)
3+	2,802 (3.86)	2,926 (4.10)	2,916 (4.24)
Medicaid-administered assistance			
No	58,511 (80.51)	57,941 (81.11)	55,803 (81.21)
Yes	14,165 (19.49)	13,493 (18.89)	12,908 (18.79)
Subtrochanteric fracture			
No	65,369(89.95)	63,832 (89.36)	61,179 (89.04)
Yes (820.22 or 820.32)	7,307 (10.05)	7,602 (10.64)	7,532 (10.96)

* Medicare beneficiaries treated with internal fixation who were sixty-five years of age or older and not enrolled in managed care; those treated with total hip arthroplasty were excluded.

Table 2.2: Adjusted rates of intramedullary nail use per 100 Medicare beneficiaries* with an intertrochanteric fracture: comparison of Wyoming with all United States in 2000-2002

	2000		2001		2002	
	Wyoming	**All states**	**Wyoming**	**All states**	**Wyoming**	**All states**
Adjusted IMN rate†	7.519		9.091		10.924	
Median		5.923		7.928		14.017
Mean		7.839		10.879		16.984
25th percentile		3.857		6.066		10.394
75th percentile		8.877		11.899		18.857

* Medicare beneficiaries treated with internal fixation who were sixty-five years of age or older and not enrolled in managed care; those treated with total hip arthroplasty were excluded.

†Adjusted for patient age, sex, race, Charlson score, subtrochanteric fracture, and Medicaid-administered assistance status.

Table 2.3: Odds ratios of receiving an intramedullary nail versus plate/screws for an intertrochanteric femur fracture in elderly Medicare beneficiaries 2000-2002, controlling for patient factors

Predictors		**Odds ratio**	**95% CI for odds ratio**	**Wald Chi-square**	***p*-value**
Surgeon state (50df)	compared to Wyoming*	§	§	4436.6499	<0.0001
Year	2000*	1.000	-	-	-
	2001	1.444	1.391 – 1.499	376.4089	<0.0001
	2002	2.490	2.404 – 2.578	2616.7653	<0.0001
Covariates					
Age					
	65-69*	1.000	-	-	-
	70-74	1.083	1.026 – 1.143	8.2902	0.0040
	75-79	1.039	0.994 – 1.086	2.8509	0.0913
	80-84	1.020	0.980 – 1.061	0.9476	0.3303
	85-89	0.998	0.960 – 1.038	0.0073	0.9318
	90+	0.961	0.809 – 1.140	0.2104	0.6464
Sex					
	Male*	1.000	-	-	-
	Female	0.951	0.920 – 0.983	8.8050	0.0030
Race					
	White*	1.000	-	-	-
	Black	1.138	1.054 – 1.228	11.0345	0.0009
	Other	1.094	1.000 – 1.197	3.8337	0.0502
Charlson score					
	0*	1.000	-	-	-
	1	1.003	0.973 – 1.034	0.0310	0.8602
	2	1.009	0.964 – 1.056	0.1447	0.7036
	3+	1.054	0.982 – 1.132	2.1450	0.1430
Medicaid-administered assistance					
	No*	1.000	-	-	-
	Yes	1.061	1.023 – 1.100	9.9394	0.0016
Subtrochanteric fracture					
	No*	1.000	-	-	-
	Yes	5.018	4.854 – 5.187	9037.5609	<0.0001

§ Individual state comparisons not shown
*Indicates reference level for odds ratios

Figure 2.1: Map of the adjusted state rates of intramedullary nail use per 100 Medicare patients treated surgically for an intertrochanteric fracture in 2000

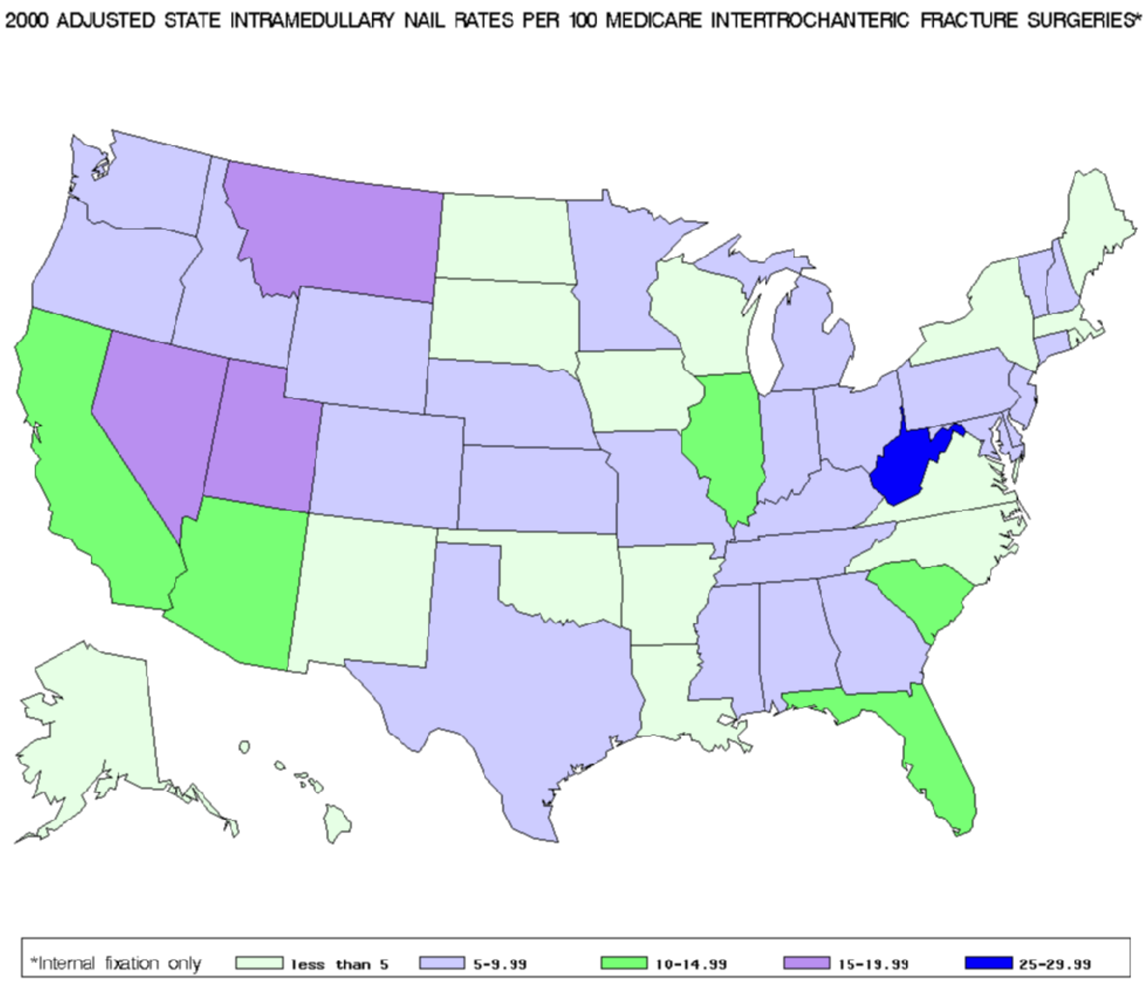
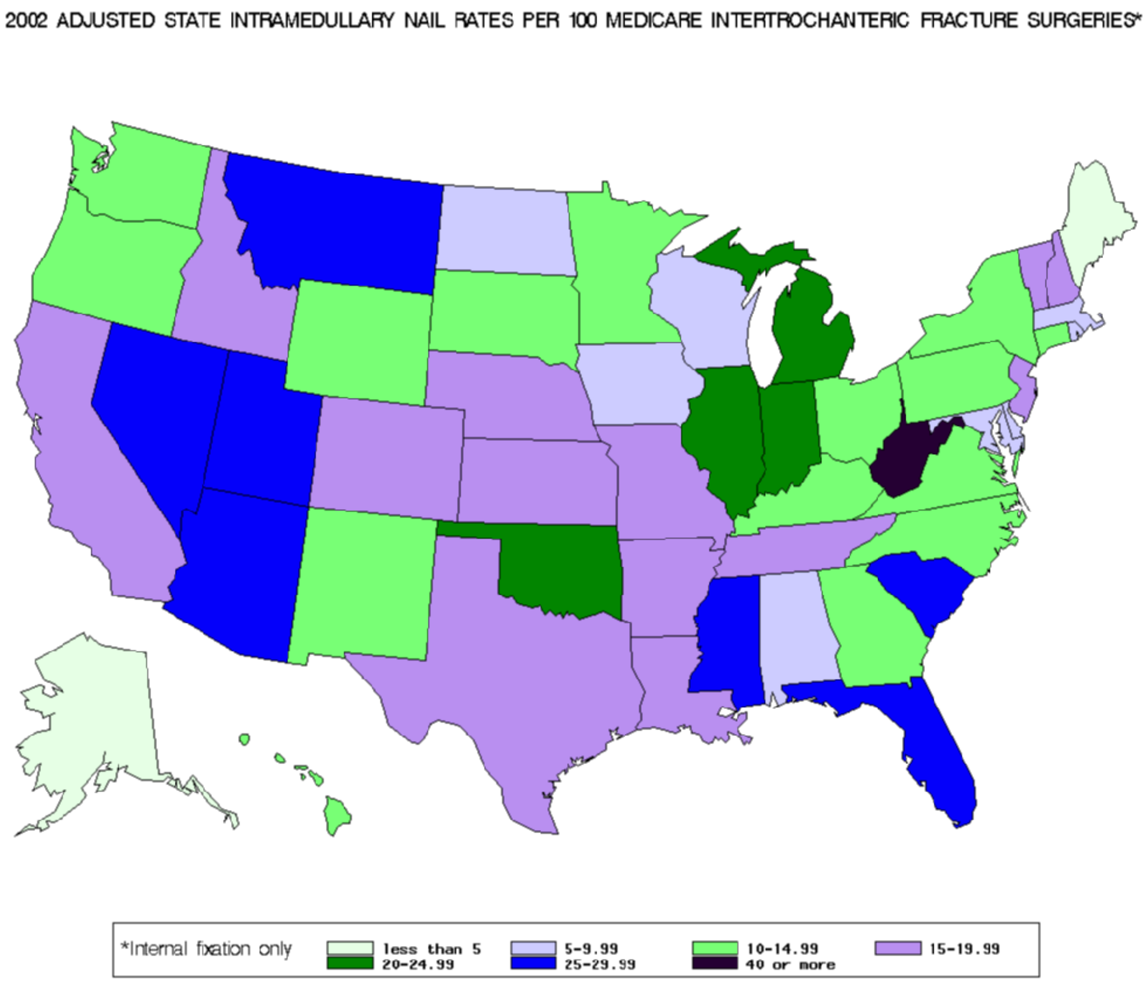


Figure 2.2: Map of the adjusted state rates of intramedullary nail use per 100 Medicare patients treated surgically for an intertrochanteric fracture in 2002



CHAPTER 3: MANUSCRIPT 2

SURGEON AND HOSPITAL FACTORS ASSOCIATED WITH THE USE OF DIFFERENTIALLY-REIMBURSED HIP FRACTURE PROCEDURES IN MEDICARE

I. Abstract

Background: Research on orthopaedic device use has largely focused on implant indications and patient outcomes, with less emphasis placed on surgeon and hospital factors that are associated with device selections. The goal of this study was to identify the surgeon and hospital characteristics that were associated with the use of intramedullary nails (IMN) versus plate/screw devices among elderly Medicare beneficiaries with intertrochanteric hip fractures. No clear outcomes benefit exists for IMN in the majority of intertrochanteric hip fracture patients. **Methods**: Medicare 100% files (MedPAR, Part B claims and enrollment) for 2000-02 were used to identify beneficiaries age 65 or older who underwent inpatient surgery to treat an intertrochanteric femur fracture using IMN or plate/screws. Surgeon and hospital characteristics from the MPIER physician enrollment and Provider of Services (hospital) files were merged with the claims. Generalized linear mixed models with fixed and random effects modeled the association between surgeon and hospital factors, and IMN use (versus plate/screws), after adjustment for patients' age, sex, race, subtrochanteric fracture, Charlson comorbidity score, nursing home residence and Medicaid-administered assistance. The adjusted odds ratios of receiving an IMN by year, surgeon and hospital factors are reported. **Results**: 192,365 claims for surgeries to treat intertrochanteric hip fractures met inclusion criteria and matched with surgeon and hospital information. 15,091 surgeons performed Medicare intertrochanteric femur fracture surgeries in 3,480 hospitals between 3/1/00 and 12/31/02. The surgeon factors associated with IMN use included younger surgeon age (<45 years), an osteopathy degree and operating at more than one hospital. The hospital factors associated with IMN use included higher hip fracture case volume, teaching hospital status and resident case involvement. Surgeon factors improved model fit more than hospital factors. **Conclusions**: The use of IMN

was strongly associated with early-career surgeons and surgeon training programs. Our findings suggest that orthopaedic faculty at teaching hospitals and younger surgeons may be selecting orthopaedic implants based on factors other than clinical outcomes studies, and that IMN device selections are reinforced by higher Medicare payments to surgeons for IMN procedures.

II. Background

More than 266,000 hip fractures occur annually in the United States, and most affect elderly individuals[1]. Geriatric hip fractures are associated with high morbidity and mortality[7-9, 48, 124-126]. Intertrochanteric hip fractures, which occur in the proximal portion of the femur between the greater and lesser trochanters, account for nearly half of all elderly hip fractures (47%)[18-21].

The majority of intertrochanteric hip fractures are surgically treated with one of two types of internal fixation devices: a plate-with-screws device (plate/screws) or an intramedullary nail (IMN) implant. There are no outcomes benefits for IMN compared with plate/screws in the treatment of stable intertrochanteric fractures[23, 26, 32, 39] which account for up to 70% of cases[127-129]. IMNs are preferred by many surgeons in patients with *unstable* fractures that extend below the lesser trochanter (*subtrochanteric*)[29, 40, 56], although definitive outcomes support for IMN in unstable fractures has not been shown[22, 23, 29].

Since 1992, Medicare has paid surgeons more to use IMN than plate/screws, due to the higher assigned Relative Value Units (RVUs) for IMN procedures. In contrast, hospitals are paid under the same Diagnosis Related Groups (DRGs) for both the IMN and plate/screws procedures, although the IMN implants cost hospitals up to $1000 more per implant than plate/screws. Despite equivalent outcomes and higher implant-related complication rates[22, 23, 35], IMN use in the United States has continued to rise and now comprises approximately 60% of the internal fixation devices used to treat intertrochanteric hip fracture patients[34, 36, 37]. Additionally, substantial geographic variation in IMN use has been identified among Medicare intertrochanteric hip fracture patients, which was not explained by patient-related factors[34, 106].

Non-patient factors that are associated with increased IMN use among Medicare patients have not been examined. The goal of this study was to identify the surgeon and hospital factors that were associated with IMN use among Medicare intertrochanteric hip fracture patients treated with internal fixation during 2000-02, controlling for patient factors.

III. Methods

Data sources and case selection

Medicare claims and enrollment data from March 1, 2000, through December 31, 2002, were used to identify Parts A- and B-enrolled, non-managed care Medicare beneficiaries, age 65 or older, who underwent an inpatient surgery to treat an intertrochanteric femur fracture using either an IMN or a plate/screws device. We used 2000-2002 as the study period because IMN devices were in widespread use in the United States, and did not undergo design modifications from 1998 through 2002.

Patient data were obtained from the 100% Medicare Provider Analysis and Review (MedPAR) hospital claim files, the Medicare Carrier (physician) claim files and the Denominator (enrollment) files. Surgeon and hospital characteristics were determined from the Medicare Physician Identification and Eligibility Registry (MPIER) file and the Medicare Provider of Services (POS) facility file, and merged with the claims using the unique Medicare provider numbers.

Surgery dates were matched by patient identifier across the hospital and physician claims within a plus or minus 7 day time window[105]. For patients with more than one intertrochanteric hip fracture during the study period, only the first surgical claim was retained. Since our interest was in index, low-energy elderly hip fractures, we excluded patients whose hospital claim indicated surgery for complications or revisions of previous hip surgery, metastatic or associated cancers, infection, bilateral fractures or high-energy trauma. Additional case selection details were previously reported[106].

The study was reviewed by the University of Minnesota Institutional Review Board and determined to be exempt.

Variables

The dichotomous outcome of interest was the type of implant used, either an IMN or plate/screws. The CPT procedure code on the surgeon's claim enabled us to determine the specific internal fixation device used in each patient. The unit of analysis was the patient. Surgeon and hospital characteristics were used as predictors while controlling for patient factors. A year indicator was also included to account for changes in IMN use over time.

Each surgeon's Medicare intertrochanteric fracture case volume was calculated as the total number of internal fixation procedures performed per surgeon provider number between March 1, 2000 and December 31, 2002. Surgeon volume was categorized into quartiles to facilitate comparison. As an estimate of surgical experience, each surgeon's age in years was calculated from their date of birth in the MPIER file to December 31, 2001, then divided into 5-year age categories. Orthopaedic Board certification status (yes, no) and professional degree (medical doctor (MD), doctor of osteopathy (DO)) were determined from the MPIER file, while practice structure (group, other) was determined from both the MPIER file and the Carrier claims. The number of hospitals where intertrochanteric hip fracture patients were treated per individual surgeon (*number of case hospitals*) was determined from the number of unique hospital identifiers present per surgeon identifier (1, 2, 3, 4+) in the claims.

Hospitals' intertrochanteric fracture volume was calculated as the total number of Medicare internal fixation surgeries for intertrochanteric hip fractures per hospital identifier during the 34-month study period. Hospitals' case volume was grouped into a 4-level categorical variable by volume quartiles. Type of hospital ownership (for-profit, non-profit, government) and teaching status (non-teaching, teaching without any resident case(s), teaching with 1+ resident case(s)) were determined from the POS file, and medical resident case involvement under the direction of a teaching physician was determined by the presence of a –GC modifier on the CPT code from the surgeon's Carrier claim[130, 131].

Our models contained patient factors that potentially influence device choice, including age (65-74, 75-84, ≥ 85 years), sex, race (white, black, other), pre-fracture nursing home residence (yes, no), subtrochanteric fracture and state Medicaid-administered assistance. We considered patients to have resided in nursing homes at the time of fracture if we identified at least one Medicare Part B provider claim that took place in a nursing home within two months preceding the hip surgery date using the *Place of Service* code from any provider's Carrier claim[132]. To control for differences in socioeconomic status, patients who received state Medicaid-administered assistance during their hospital stay were identified from monthly enrollment indicators in the Denominator file. We then created a four-level categorical variable by cross-classifying pre-admission residence (nursing home or other) with state Medicaid-administered assistance status (yes or no) to avoid potential bias from nursing home patients in the regression coefficient for state Medicaid-administered assistance. The adapted Charlson comorbidity scores (0, 1, 2, ≥ 3)[50, 51] were excluded from our final models due to lack of significance in predicting device choice in all preliminary models, which was consistent with prior work on patient factors that used device choice as the outcome[106].

Models were tested by calendar year then pooled for the final analyses due to the consistency of our findings over time. We excluded cases with surgical dates prior to March 1, 2000 to allow for the two-month nursing facility claim look-back, which resulted in a 34-month analytic file.

Statistical Analyses

We used generalized linear mixed models with fixed and random effects to model the association between surgeon and hospital factors, and the dichotomous outcome of device choice (IMN or plate/screws), while controlling for patient factors. These models can account for the correlated nature of the data, nonlinear associations between the independent predictors and the device choice outcome, and imperfect nesting of surgeons within hospitals[109, 110]. Patients in this study were perfectly nested within surgeons but surgeons often operated at several hospitals, with just over half of surgeons operating at only one hospital during the study period. Since generalized linear models are likelihood based, the standard likelihood ratio tests were used to compare nested models[109]. Non-nested models were compared using information criteria, which penalizes the log likelihood for the number of model parameters (Akaike Information Criterion, AIC) or subjects (Bayesian Information Criterion, BIC), with smaller values indicating better fit of the model to the data[109].

We considered three types of models: fixed (means) without random effects, random hospital intercepts, and random surgeon intercepts. We examined four groups of predictors, each with and without random surgeon or hospital intercepts, for a total of 12 models, including an intercept-only model, patient factors with year, patient and surgeon factors with year, and patient, surgeon and hospital factors with year, for which AIC and BIC model fit estimates are reported. Analyses were conducted using the SAS statistical program, NLMIXED, version 9.1 for Windows (SAS Institute, Inc., Cary, NC, USA)[111]. Coefficient estimates, standard errors, odds ratios (OR) and 95% confidence intervals (CI) for the odds ratios are reported for the surgeon, hospital and year predictors of the best fitting model only; odds ratios only are reported for model comparisons. Descriptive statistics are reported as percent, mean or median.

IV. Results

Sample description

Between 3/1/00 and 12/31/02, 192,365 Medicare claims for intertrochanteric hip fracture surgeries met our inclusion criteria and matched with complete surgeon and hospital information (98.2% matched). Intertrochanteric hip fracture surgeries with internal fixation were performed by 15,091 surgeons in 3,480 United States hospitals for non-managed care Medicare beneficiaries during that time period. The proportion of intertrochanteric hip fracture patients who received an intramedullary nail versus plate/screws increased from 8.1% of cases in 2000 to 17.1% percent in 2002.

The provider characteristics are described in Table 3.1. The median age among surgeons was 46 years. Over the 34 month study period, surgeons' median intertrochanteric hip fracture volume was 10 cases (average 3.4 cases per year); 7.8% of surgeons operated on only one patient during the study. Surgeons with MD degrees comprised 95.4% of the providers, and surgeons were almost exclusively self-identified as orthopaedic surgeons (98.4%). Nearly two-thirds of surgeons were Orthopaedic

Board-certified (64.9%); 64.2% practiced in a group practice. Just over half of surgeons operated at only one hospital (55.0%), while 14.2% of surgeons operated at 3 or more hospitals during the study.

The median number of Medicare intertrochanteric hip fracture patients treated per hospital was 41 cases over 34 months, or approximately 14 patients per year (Table 3.1). Eighty hospitals (2.3%) surgically treated only one internal fixation hip fracture patient during the study period. Two-thirds of the case hospitals were non-profit facilities (66.9%). The majority of hospitals were not teaching facilities (69.1%). Only 150 hospitals (4.3%) were teaching hospitals that had resident case involvement, and an additional 26.6% of hospitals were identified as teaching hospitals without resident assistance during hip fracture surgeries.

The patients were, on average, 84 years of age (Table 3.2), largely female (77.2%), and most were white (94.6%). Subtrochanteric fractures were identified in 10.6% of cases. One-fifth of patients were admitted from a nursing home with a hip fracture (20.1%). The majority of patients did not receive state Medicaid-administered assistance (80.8%).

Surgeon random intercepts model

The results from the surgeon random intercepts model, which provided the best fit to the data, are shown Table 3.3. The odds of intertrochanteric hip fracture patients receiving an IMN device in the year 2001 were 1.8 times higher than in 2000, and nearly 5 times higher in 2002 compared with 2000 (OR 4.68, 95% CI 4.40-4.97).

There was an inverse relationship between age of the surgeon and IMN use. After controlling for patient and other provider factors, surgeons under age 45 had higher odds of IMN use compared with median-age surgeons (45-49 years), with the highest comparative odds of IMN use among the youngest group of surgeons (age <35 years, OR 5.13, 95% CI 3.87- 6.81). Surgeons age 50 or older had significantly lower odds of selecting IMN than 45-49 year old surgeons, however, the standard errors for surgeons age 50 or older were slightly larger than for those under age 45, indicating potentially larger device choice variability among the older surgeons.

Surgeons' number of intertrochanteric hip fracture cases was not significantly associated with device selection. The odds of receiving an IMN device among patients of surgeons who performed 4 or fewer cases over the 34 months were not significantly different than the odds of receiving IMN among patients of the highest volume surgeons (18+ cases). Although not statistically significant, there is a U-shaped trend in the odds ratios of IMN use by surgeon volume categories, with lower values among mid-volume surgeons relative to the highest and lowest volume providers.

The odds ratios of IMN use increased as surgeons' number of case hospitals increased. Patients of surgeons who performed hip fracture surgeries at 4 or more hospitals had more than double the odds of receiving an IMN device than patients of surgeons who operated only at one hospital, controlling for other factors (OR 2.44, 95% CI 1.76-3.38).

Patients treated by Doctors of Osteopathy had twice the odds of receiving an IMN device than patients of MDs, although doctors in the United States holding either degree attend the same orthopaedic residency and fellowship training programs.

Orthopaedic Board-certification and practice structure were not significantly associated with IMN use. A provider specialty indicator variable (orthopaedic, other) was omitted from the final models because it was not significantly related to device choice in all preliminary models among this almost exclusively orthopaedic provider group.

Hospitals' volume of Medicare intertrochanteric hip fracture patients was positively associated with IMN use (Table 3.3). Compared with the highest volume hospitals (79+ cases overall, corresponding to 28+ cases per year), patients surgically treated in hospitals that performed less than the median volume of 41 cases during the study had 16-17% lower odds of receiving an IMN, controlling for other factors. Hospitals that performed just above the median number of cases (3^{rd} volume quartile) were equally likely to use IMN as hospitals in the highest hip fracture volume quartile.

Patients treated at teaching hospitals with no resident cases had 12% higher odds of receiving an IMN for their fracture than patients treated at non-teaching facilities. Moreover, patients whose surgeries were performed at a teaching hospital with resident cases had 58% higher odds of receiving an IMN device than patients treated at non-teaching hospitals, controlling for patient and other provider factors. IMN use did not significantly differ by the type of hospital ownership.

Patient covariates

Consistent with the orthopaedic literature, patients with unstable subtrochanteric fractures had substantially higher odds of IMN use, compared with other pertrochanteric fractures (OR 17.51, 95% CI 16.47-18.61, Appendix D), although only one-third of subtrochanteric fracture patients received an IMN during this period. Consistent with previous work[106], the influence of other patient factors on IMN use in the models were generally modest and tended to contradict the device use expectations based on claim factors that correlate with clinical factors, such as low bone density[44, 120].

Model comparisons

The odds ratios of receiving an IMN device versus plate/screws from each of the three models with the full set of predictors are shown in Table 3.4. The findings are highly consistent across all three models. There are differences in the magnitude of each factor's influence across models, but the direction of the influence of each predictor on IMN use essentially did not change, regardless of the model used. The odds ratios for the influence of surgeon's age, professional degree, number of case hospitals, hospital's teaching status and hospital's case volume were particularly stable across all models. The effect of surgeon's case volume was similar across the three models, but was not a significant predictor of device choice in the model with surgeon random intercepts, suggesting a great deal of variation in IMN use among providers within the surgeon volume categories. The magnitude of the odds ratios of IMN use, particularly among young surgeons (age < 40 years) showed dramatic increases using the surgeon random intercepts model.

Model fit

The models with either surgeon or hospital random effects had significantly better fit than the models without random effects (likelihood ratio tests p<0.0001, results not shown). The surgeon random intercepts models better fit the data (lower AIC) than the hospital random intercepts models when evaluated by AIC and BIC (Appendix E), which indicates that heterogeneity in IMN use among surgeons was more pronounced than heterogeneity in IMN use among hospitals. The model that contained patient, surgeon and hospital predictors with surgeon random intercepts best fit the data (AIC=80,541). However, after the inclusion of the surgeon random effects (AIC=80,560), the addition of the hospital predictor variables only minimally improved the model fit (AIC 80,541).

V. Discussion

We found a strong association between surgeon factors, teaching hospital status (with and without resident case involvement), and hospital volume and IMN use in the treatment of Medicare intertrochanteric hip fracture patients during 2000-2002. Surgeon factors accounted for more of the variation in IMN use than the hospital factors we examined.

Younger surgeons were the primary adopters of IMN, likely reflecting higher IMN use in surgeries performed at the teaching hospitals that trained them. Given the higher RVUs for IMN procedures, we expected the odds of IMN to be higher among mid-career, board-certified surgeons in group practices[65, 102] who had attained some degree of experience and surgical proficiency that would enable them to master a new procedure that is paid to require more planning, technical skills, greater judgment and longer time to perform than plate/screws hip fracture procedures. Instead, we found the highest IMN use among the youngest of surgeons, presumably with the least experience. Our findings suggest that younger surgeons continue to perform the procedures that they become familiar with in training, while older surgeons, who may be more comfortable or proficient with plate/screws surgeries, were less likely to change to the newer IMN procedures.

Our findings challenge the assumption that IMN procedures require superior surgical skills and surgeon judgment, given the IMN adoption pattern found among the youngest and least experienced surgeons, assuming that both surgical skill and judgment improve with experience. Our finding of high IMN use among young surgeons is consistent with recent IMN use patterns noted in the American Board of Orthopaedic Surgery data[34].

After controlling for patient and other provider factors, we found higher odds ratios of IMN use among surgeons who operated at more than one hospital, particularly among surgeons who operated at 4 or more hospitals. Compared with one-hospital surgeons, poly-hospital (4+ facilities) surgeons were younger (median age 42 versus 47 years), had a higher average case volume (17 versus 7 cases) and more often held a DO versus MD degree (10.2% versus 3.7%), but the difference persisted when these factors were controlled. Lower use of IMN among one-hospital surgeons may reflect their greater cognizance of the facility costs incurred by their device choices within their host hospitals, rather than their slightly higher median age.

One-third of hospitals in this study were staffed by at least one poly-hospital surgeon, and these hospitals tended to be moderate-to-high volume, non-government facilities. A greater proportion of the hospitals used by poly-hospital surgeons were teaching hospitals, and these teaching hospitals had the same proportion of surgical resident cases as in hospitals without poly-hospital surgeons. These findings, combined with higher IMN use in high volume hospitals, suggest that factors other than orthopaedic surgeon coverage or resident availability, such as faster IMN procedure times, may be a factor in IMN use that allows for more rapid operating room turnover in high volume hospitals, thereby at least partially offsetting higher IMN device costs to hospitals over plate/screws implants.

The modestly higher IMN use among teaching hospitals compared with non-teaching hospitals reflects their earlier adoption of new technology[68, 102]. Academic surgeons at teaching hospitals may feel a responsibility for educating surgeon trainees in state-of-the-art techniques; academic surgeons may also be more likely to work closely with manufacturers to design and test new devices. The orthopaedic device industry may be more willing to give teaching hospitals volume discounts on implants in the hopes of exposing a new cohort of surgeons to these devices. Although teaching hospitals may treat patients with more severe case mix profiles than non-teaching facilities, the substantially higher odds of receiving an IMN device in a hospital with resident cases, compared to one without resident cases, suggests that there may be differences in patient selection for surgeries where resident involvement is allowed, or other IMN incentives that uniquely affect resident-supervising surgeons that we were not able to account for in this analysis.

Two important strengths of this claims-based study include the large number of hip fracture cases for which we were able to evaluate device-related provider patterns, and the inclusion of multiple patient and provider variables to predict the device choice outcome.

We acknowledge several important limitations of our study. Our analysis incorporated only one random effect at a time, which limited our ability to analyze provider patterns with higher degrees of nesting. However, given the stability of the direction of the findings across the models examined, we do not expect that alternative models would change the overall findings.

The patients in this study were in fee-for-service Medicare only; full provider volumes, especially in areas of high managed care enrollment, are not reflected. Given the insignificant effect of surgeon volume on IMN use, potential under-classification of surgeon volume in several states that had high Medicare managed care enrollment would most likely not change our overall surgeon volume conclusions. We would expect any misclassification of hospital volume to enhance or not substantially change our hospital volume conclusions, given the positive direction of the volume effect on IMN use. We would not expect subtrochanteric fracture rates or fracture patterns that may impact device selection to differ by type of insurance, nor would we expect surgeons to make device choices based on managed care enrollment status.

We were unable to account for other factors that may influence surgeons' device choice for Medicare intertrochanteric hip fracture patients, including specific fracture patterns, procedure speed and ease, marketing and related device industry influences, clinical patient features and surgeons' opinions about which fracture patterns are unstable, none of which are available in claims-based studies. There remains no consensus among surgeons as to which intertrochanteric fracture patterns constitute unstable fractures. Thus, the decision to label a fracture as *unstable* relaxes the clinical criteria necessary to justify the selection of an IMN device, by incorrectly assuming consistency in the stable/unstable distinction across clinical studies.

Practice structure and Orthopaedic Board-certification status were not significantly associated with IMN use, but may be under-identified in this study. Board-certification status is not required Medicare provider enrollment information[133, 134], and if obtained, may only be updated for practice site changes. Neither variable affects Medicare payments to surgeons, and the validity of the MPIER Board-certification and group practice estimates specifically among orthopaedic surgeons has not been examined[134].

Finally, hospitals' elderly Medicare intertrochanteric hip fracture volume may not parallel hospitals' overall orthopaedic case volume. Thus, we advise caution in generalizing our volume findings.

Conclusion

The use of IMN devices was strongly associated with early-career surgeons and surgeon training programs. Despite talk about evidence-based medicine, our findings suggest that orthopaedic faculty at teaching hospitals and younger surgeons may be selecting orthopaedic implants based on factors other than clinical outcomes studies, and that IMN device selections are reinforced by higher Medicare payments for IMN procedures. We expect that IMN use will continue to increase as long as new surgeons are preferentially trained in IMN, and a Medicare IMN payment incentive remains. We recommend further analysis to determine how these IMN-related provider patterns affect Medicare patient outcomes after intertrochanteric hip fracture surgeries.

Table 3.1: Surgeon and hospital characteristics among Medicare intertrochanteric hip fracture patients 2000-02*

Variable	% of providers
Surgeon factors 15,091 surgeons	
Surgeon age (years)	
< 35	8.57
35-39	17.13
40-44	17.94
45-49	18.02
50-54	14.44
55-59	12.02
60-64	7.96
65 or older	3.92
Number of case hospitals	
1	54.98
2	30.83
3	9.97
4 or more	4.22
Surgeon case volume*	
1-4	24.62
5-10	26.60
11-17	22.83
18 or more	26.05
Professional degree	
Medical doctor (MD)	95.44
Doctor of Osteopathy (DO)	4.56
Orthopaedic Board certification	
Board certified	64.92
Not Board certified	35.08
Practice structure	
Group practice	64.24
Other	35.76
Hospital factors 3,480 hospitals	
Teaching status	
Non-teaching	69.08
Teaching – no resident case(s)	26.61
Teaching – with resident case(s)	4.31
Hospital case volume*	
1-17	25.66
18-41	24.68
42-78	24.94
79 or more	24.71
Type of ownership	
Non-profit	66.90
For profit	14.77
Government	18.48

*intertrochanteric hip fracture patients treated with internal fixation, 3/1/2000 - 12/31/2002

Table 3.2: Patient characteristics among Medicare intertrochanteric hip fracture cases 2000-02*

Patient factor	**% of patients**
Age	
65-74	12.31
75-84	39.43
85 years or older	48.27
Sex	
Male	22.84
Female	77.16
Race	
White	94.57
Black	3.15
Other	2.29
Type of fracture	
Subtrochanteric	10.59
Other pertrochanteric	89.41
Residence-state assistance status	
Non-nursing home, no state assistance	68.27
Nursing home, no state assistance	12.51
Non-nursing home, has state assistance	11.68
Nursing home, has state assistance	7.54

*192,365 patients treated with internal fixation, 3/1/2000 - 12/31/2002

Table 3.3: Surgeon random intercepts model results: surgeon and hospital factors**

SURGEON FACTORS	Coefficient	SE	Odds ratio	95% CI
Surgeon age				
< 35	1.635	0.144	**5.13***	3.87 – 6.81
35-39	0.947	0.117	**2.58***	2.05 – 3.24
40-44	0.333	0.114	**1.40**	1.17 – 1.75
45-49§	-	-	1.00	-
50-54	-0.241	0.122	**0.79**	0.62 - 0.99
55-59	-0.495	0.130	**0.61**	0.47 – 0.79
60-64	-0.364	0.153	**0.70**	0.52 – 0.94
≥ 65	-0.452	0.211	**0.64**	0.42 – 0.96
Surgeon case volume#				
1-4	0.206	0.108	1.23	0.99 – 1.52
5-10	-0.124	0.093	0.88	0.74 – 1.06
11-17	-0.158	0.094	0.85	0.71 – 1.03
18 or more§	-	-	1.00	-
Number of case hospitals				
1§	-	-	1.00	-
2	0.187	0.078	**1.21**	1.03 – 1.41
3	0.382	0.117	**1.47***	1.17 – 1.84
4 or more	0.893	0.166	**2.44***	1.76 – 3.38
Professional degree				
Medical doctor (MD) §	-	-	1.00	-
Doctor of Osteopathy (DO)	0.723	0.159	**2.06***	1.51 – 2.81
Orthopaedic Board certification				
Board certified §	-	-	1.00	-
Not Board certified	0.119	0.773	1.13	0.97 – 1.31
Practice structure				
Group practice§	-	-	1.00	-
Other	-0.006	0.069	0.99	0.87 – 1.14
HOSPITAL FACTORS				
Hospital case volume#				
1-17	-0.186	0.084	**0.83**	0.70 – 0.98
18-41	-0.174	0.059	**0.84**	0.75 – 0.94
42-78	-0.066	0.046	0.94	0.86 – 1.02
79 or more§	-	-	1.00	-
Teaching status				
Non-teaching§	-	-	1.00	-
Teaching –no resident case(s)	0.114	0.043	**1.12**	1.03 – 1.22
Teaching- with resident case(s)	0.460	0.118	**1.58***	1.26 – 2.00
Type of ownership				
Non-profit§	-	-	1.00	-
For profit	0.097	0.057	1.10	0.99 – 1.23
Government	0.050	0.061	1.05	0.93 – 1.19
Year				
2000§	-	-	1.00	-
2001	0.572	0.031	**1.77***	1.67 – 1.88
2002	1.543	0.031	**4.68***	4.40 – 4.97

p-value: **bold** = p<0.05, **bold*** = p<0.0001 **§** =reference level
Medicare intertrochanteric hip fracture patients treated with IMN or plate/screws between 3/1/00 and 12/31/02
** Controlling for patient age, sex, race, nursing home residence, subtrochanteric fracture and Medicaid assistance

Table 3.4: Model comparisons: Odds ratios of IMN use **

Predictor	No random effects	Random surgeon intercepts	Random hospital intercepts
SURGEON FACTORS			
Surgeon age			
< 35	**1.76***	**5.13***	**2.16***
35-39	**1.36***	**2.58***	**1.59***
40-44	1.04	**1.40**	**1.16***
45-49§	1.00	1.00	1.00
50-54	**0.83***	**0.79**	**0.81***
55-59	**0.62***	**0.61**	**0.62***
60-64	**0.80***	**0.70**	**0.76***
≥ 65	**0.63***	**0.64**	**0.51***
Professional degree			
Medical doctor (MD) §	1.00	1.00	1.00
Doctor of Osteopathy (DO)	**1.38***	**2.06***	**1.42***
Orthopaedic Board certification			
Board certified §	1.00	1.00	1.00
Not Board certified	**1.08***	1.13	**1.11***
Practice structure			
Group practice§	1.00	1.00	1.00
Other	**1.13***	0.99	**1.07**
Number of case hospitals			
1§	1.00	1.00	1.00
2	**1.21***	**1.21**	**1.13***
3	**1.23***	**1.47***	**1.23***
4 or more	**1.67***	**2.44***	**1.58***
Surgeon case volume#			
1-4	1.01	1.23	**0.88**
5-10	**0.88***	0.88	**0.78***
11-17	**0.90***	0.85	**0.85***
18 or more§	1.00	1.00	1.00
HOSPITAL FACTORS			
Type of ownership			
Non-profit§	1.00	1.00	1.00
For profit	**1.23***	1.10	**1.46**
Government	1.04	1.05	1.17
Teaching status			
Non-teaching§	1.00	1.00	1.00
Teaching – no resident case(s)	**1.17***	**1.12**	**1.45***
Teaching- with resident case(s)	**2.04***	**1.58***	**2.41***
Hospital case volume#			
1-17	**0.91**	**0.83**	**0.75**
18-41	**0.89***	**0.84**	**0.75**
42-78	**0.87***	0.94	**0.78**
79 or more§	1.00	1.00	1.00
Year			
2000§	1.00	1.00	1.00
2001	**1.35***	**1.77***	**1.47***
2002	**2.26***	**4.68***	**2.90***

bold = p<0.05, **bold*** = p<0.0001
#Number of Medicare intertrochanteric fractures treated with internal fixation
* Controlling for patient age, sex, race, subtrochanteric fracture, nursing home residence and Medicaid assistance
§= reference level

CHAPTER 4: MANUSCRIPT 3

NINETY-DAY INTERTROCHANTERIC HIP FRACTURE MORTALITY: DOES PROVIDER VOLUME MATTER?

I. Abstract

Background: Orthopaedic volume-outcomes research has focused almost exclusively on elective arthroplasty procedures. Geriatric hip fracture patients are older with heavier comorbidity burden than arthroplasty patients; therefore, any provider volume advantage on mortality could be masked by the severity of the hip fracture condition itself. Our study examined the association between surgeon and hospital volume of Medicare intertrochanteric femur fracture surgeries and inpatient through ninety-day postoperative mortality. **Methods**: Medicare 100% files (hospital and physician claims, enrollment) for 2000-02 identified beneficiaries age 65 or older who underwent inpatient surgery to treat an intertrochanteric femur fracture with internal fixation (plate/screws or intramedullary nail). Surgeon factors from the MPIER file and hospital information from the Provider of Services file were merged with each claim. Fixed effects regression analysis using generalized estimating equations (GEE) was used to model the association between hospital and surgeon intertrochanteric fracture volume, surgeon age, hospital ownership and teaching status, and inpatient through 90-day mortality, controlling for patients' age, sex, race, Charlson comorbidity score, subtrochanteric fracture, pre-fracture nursing home residence, Medicaid-administered assistance, device and year. The unadjusted inpatient, 30, 60 and 90-day mortality rates and adjusted odds ratios are reported. **Results**: 192,365 claims met inclusion criteria and matched with provider information. The unadjusted inpatient, 30, 60 and 90-day mortality rates were 2.91%, 7.92%, 12.34% and 15.19% respectively. Patients treated at lower volume hospitals had significantly higher (7-21% higher) adjusted odds of inpatient mortality than those treated at the highest volume hospitals (28+ cases/year). After discharge, the higher odds of mortality persisted only among patients treated at the lowest volume hospitals (average <=6 cases/year). Patients of surgeons who treated 5-10 cases (average 2-3 cases/year) had the

highest odds (10% higher) of inpatient mortality compared with the highest volume surgeons (18+ total cases) during the study. **Conclusions:** Only the highest volume hospitals showed an inpatient mortality benefit for Medicare intertrochanteric hip fracture patients. The hospital volume disadvantage persisted from 30 to 90 days in only the lowest volume hospitals. Patients of surgeons with just below the median case volume had the odds of short-term postoperative mortality.

II. Background

A positive volume-outcomes relationship has been shown for a wide range of surgical procedures across a variety of specialties, such as cardiology and oncology[82, 83]. After adjusting for patient case-mix differences, higher surgeon and hospital procedure volumes are associated with lower mortality rates, fewer perioperative complications, and often shorter hospital stays[82-87]. Orthopaedic volume-outcomes research has focused almost exclusively on elective arthroplasty procedures, where evidence suggests that patients who undergo surgeries by low volume surgeons at low volume hospitals have higher mortality and perioperative complication rates[57, 58, 62-64, 88-90]. The specific mechanisms that account for the observed volume-outcomes benefits remain largely unidentified.

Outcomes may be the result of many factors in addition to provider case volume. Geriatric hip fracture patients are generally older with heavier comorbidity burden than elderly who undergo elective arthroplasty procedures[9, 63, 64] and they have higher generic and condition-related mortality risks than elective arthroplasty patients[7-9]. Therefore, a modest surgeon or hospital volume advantage on major adverse outcomes could be overwhelmed by the severity of the hip fracture condition itself, masking any positive effect of higher surgeon and hospital volume on postoperative mortality rates.

Using a three-year, 100% sample of Medicare claims from elderly intertrochanteric hip fracture patients, this study examined the association between surgeon and hospital volume of Medicare intertrochanteric femur fracture surgeries and inpatient through ninety-day mortality, after controlling for patient, hospital and surgeon factors, including device. This is the first population-based study to examine provider volume and device-related, ninety-day mortality for what is essentially a non-elective orthopaedic surgical procedure in the elderly. We hypothesized that patients treated in low volume hospitals or by low volume surgeons would have higher short-term mortality risks than high volume providers.

III. Methods

Data

Medicare claims and enrollment data from March 1, 2000, through December 31, 2002 were used to identify all Medicare beneficiaries who underwent an inpatient surgery to treat an intertrochanteric femur fracture using either a plate/screws or an intramedullary nail device. Patient data were obtained from the Medicare Provider Analysis and Review (MedPAR) hospital claim files, the Medicare Carrier (physician) claim files and the enrollment (Denominator) files for 2000-2002. Surgeon and hospital characteristics were determined from the Medicare Physician Identification and Eligibility Registry (MPIER) file and the Medicare Provider of Services (POS) facility file. This study was reviewed by the University of Minnesota Institutional Review Board and determined to be exempt.

Sample

Medicare beneficiaries who underwent an inpatient surgery to treat an intertrochanteric femur fracture between March 1, 2000 and December 31, 2002 were identified using diagnosis and procedure codes in the 100% MedPAR hospital claim files. Surgeon claims for procedures using either an intramedullary nail or plate/screws device for intertrochanteric fracture treatment were selected from the Carrier file by Current Procedural Terminology (CPT) codes 27244 and 27245[131]. For patients with more than one intertrochanteric fracture during the study period, only the first surgical claim was retained. Claims from the MedPAR and Carrier files were merged with the beneficiary enrollment information using a unique patient identifier. Surgeon factors from the

MPIER file were merged with the hip fracture claims using the surgeon's unique Medicare provider number (UPIN). Hospital information from the Provider of Services file was merged with the claim files using the hospital-specific provider numbers. Hospitals that experienced a provider number change due to a change in ownership or to Critical Access designation during the study period were converted to the most recent identification number for volume calculations.

Inclusion criteria

Patients who had surgery with internal fixation (intramedullary nail or plate-with-screw) for a specific ICD-9 diagnosis code[135] of pertrochanteric femur fracture (820.2x–820.3x) on either the hospital or physician claim, and were at least 65 years of age on the date of surgery were included in our analyses. Surgery dates were matched across the hospital and physician claims within a plus or minus 7 day time window[105]. We included Medicare patients who were enrolled in both Parts A and B Medicare at the time of their hip surgery and throughout the two months prior to it.

Exclusion criteria

We excluded patients whose hospital claim indicated surgery for complications or revisions of previous hip surgery, metastatic or associated cancers, infection, bilateral fractures or high-energy trauma. Patients enrolled in managed care at any time in 2000-2002 were excluded, because non-hospice managed care claims are not included in the Medicare data files. We excluded cases with surgical dates prior to March 1, 2000 to allow for a two-month nursing facility claim look-back. Further details of our case selection process were detailed in our previous work[106].

Variables

Outcomes

The outcomes of interest were cumulative inpatient, thirty, sixty and ninety-day mortality among Medicare intertrochanteric hip fracture patients surgically treated with internal fixation. Patients who were enrolled in Medicare at any time during 2000-2002 and died in 2000 through March 31, 2003 were identified from the Denominator files. Inpatient mortality was assigned if the *Discharge Status Code* in the MedPAR file indicated an inpatient death, and if a date of death for the beneficiary was present in the Denominator file. Thirty, sixty and ninety-day mortality were determined by the number of days from the hip surgery date on the surgeon's claim to the date of death in the Denominator file.

Patient factors

Models were adjusted for the claims-identified patient factors that are known or hypothesized to affect survival including age (65-74, 75-84, ≥ 85 years), sex, race (white, black, other), adapted Charlson comorbidity score (0, 1, 2, ≥ 3), pre-admission nursing home residence, subtrochanteric fracture and state Medicaid-administered assistance[7-9, 45, 48, 50, 51, 136]. Type of implant (plate/screws or intramedullary nail) was included in the models to account for potential differences in patient case-mix by device.

We considered patients to have resided in nursing homes at the time of fracture if we identified at least one Medicare (Part B) provider claim that took place in a nursing home within two months preceding the hip surgery date on the surgeon's procedure claim using the *Place of Service* code from any provider's Carrier claim[132]. This nursing facility identifier served as an added measure of patients' frailty and impairment that could not otherwise be identified using the Charlson comorbidity score from a single hospital admission. We hypothesized that nursing home patients with high Charlson scores would have higher mortality than patients with the same scores admitted from other sites.

To consider differences in socioeconomic status, patients who received state Medicaid-administered assistance during their hospital stay were identified from monthly enrollment indicators in the Denominator file. Since Medicare typically does not pay for long-term care services and because many nursing home residents are eventually on Medicaid, we created a four-level categorical variable to indicate pre-admission residence (nursing home or other) cross-classified with state Medicaid-administered assistance status (yes or no) at the time of fracture to avoid potential bias from nursing home patients in the interpretation of the regression coefficient for state Medicaid-administered assistance.

Hospital and surgeon factors

Hospitals' intertrochanteric fracture volume was calculated as the total number of Medicare internal fixation surgeries for intertrochanteric fractures per hospital between March 1, 2000 and December 31, 2002. Hospitals' case volume was then grouped into a 4-level categorical variable by volume quartiles. Type of hospital ownership (for-profit, non-profit, government) and teaching status (non-teaching, teaching without resident cases, teaching with at least 1 resident case) were included in the models based on previous work that found these factors to be associated with intramedullary nail use or mortality[69, 137, 138]. Resident case involvement under the direction of a teaching physician was determined by the presence of a –GC modifier on the CPT code from the surgeon's procedure claim[130, 131].

Each surgeon's Medicare intertrochanteric fracture case volume was calculated as the total number of internal fixation procedures performed per surgeon during the 34-month study period. Surgeon volume was then divided into a four-level categorical variable by volume quartiles for ease of comparison. As an estimate of surgical experience, each surgeon's age in years was calculated from their date of birth in the MPIER file to December 31, 2001, then divided into a 3-level categorical variable of age tertiles.

Model exclusions

Additional surgeon factors that were previously found to be associated with intramedullary nail use but were not significantly related to mortality in preliminary analyses were excluded from the final models[137]. These factors included the surgeon's professional degree (MD or DO) and each surgeon's number of case hospitals (one/more than one).

We examined the number of blood units billed and noted that blood use differed by device, with plate/screws patients receiving more blood ($p<0.0001$). We therefore excluded blood units from our final models, because controlling for a consequence of the device choice would lead to underestimation of the association between device and the mortality outcome of interest.

Although the optimal timing of hip fracture surgery remains unresolved, a number of studies have demonstrated an association between longer admission to surgery delays and higher rates of mortality and adverse outcomes[139-141]. We examined the unadjusted association between delay to surgery (≤1, 2-3, or ≥4 calendar days) and hospital volume and found that delays of two or more days varied by hospital volume, with a greater proportion of cases in hospitals with median or lower intertrochanteric fracture volume had longer admission to surgery delays. We then examined the hospital volume-mortality association with and without delay to surgery in our logistic regression models, and found that the odds ratios for the hospital volume quartiles changed maximally by 2.0% in the lowest volume hospitals only with the addition of delay. All other model factors were not affected by adding delay to surgery to the models. Additionally, we examined the unadjusted hospital volume-mortality association by device separately and found that a slightly greater percent of intramedullary nail than plate/screws patients had longer delays from admission to surgery. However, there was no clear pattern in these differences by hospital volume quartiles. Delay to surgery and blood units billed were therefore excluded from our final models, and were instead hypothesized to explain the mechanisms underlying the volume and device-related findings.

Statistical analysis

All analyses were conducted using the SAS statistical program, version 9.1 for Windows (SAS Institute, Inc., Cary, NC, USA)[111]. Unadjusted mortality is reported as the number and percent of deaths among Medicare intertrochanteric femur fracture patients treated with internal fixation between March 1, 2000 and December 31, 2002, using the total number of internal fixation cases as the denominator. Categorical variables are reported as frequency and percent of internal fixation cases. Continuous variables are reported as mean or median values then analyzed as categorical variables in the regression models for ease of comparison. Initial bivariate associations between categorical predictor variables and mortality were examined using chi-square tests. Homogeneity of the odds ratios across multilevel categorical predictors were assessed using chi-square tests.

Separate multiple logistic regression models were used to examine the association between device, surgeon and hospital volume with inpatient, 30, 60 and 90-day mortality, after controlling for other patient, surgeon and hospital factors. The unit of analysis was individual patients. Fixed effects regression analyses using generalized estimating equations (GEE) were used to account for the similarities among patients treated within the same hospital. The GEE models assume that outcomes for patients treated within the same hospital are correlated, but independent across hospitals[107]. Models were initially tested by calendar year to assess time trends then pooled for the final analyses due to consistency of our findings over time. Results are reported as the odds ratios of mortality for patients with a specific predictor value compared with the reference group of that factor, after controlling for all other model factors. The highest pooled case volume quartiles for surgeons (18 or more) and hospitals (79 or more) served as the volume reference groups, and the oldest group of surgeons (age 50 or older) as the surgeon's age reference group for regression analyses. Tests for linear trend in mortality across the surgeon and hospital volume levels were performed.

The final regression models included hospital and surgeon intertrochanteric fracture volume, surgeon age, the type of hospital ownership and hospital teaching status as predictors of mortality, controlling for patients' age, sex, race, adapted Charlson comorbidity score, subtrochanteric fracture, pre-fracture nursing home residence, Medicaid-administered assistance status, device and year (2000-02).

IV. Results

Between March 1, 2000 and December 31, 2002, 192,365 Medicare patient claims for intertrochanteric hip fracture surgeries met our inclusion criteria and matched with complete surgeon and hospital information (98.2% matched).

Demographics

The characteristics of intertrochanteric hip fracture patients during the 34-month study period were highly consistent (Table 4.1). The average patient age was 84 years and more than three-fourths of all patients were female (77.2%). The vast majority of patients were white (94.6%) and did not have a subtrochanteric fracture (89.4%). One in five (20.1%) Medicare intertrochanteric fracture patients lived in a nursing home at the time of their hip fracture. More than half (51.2%) of all intertrochanteric fracture patients had a Charlson comorbidity score of one or higher. Overall, the presence of dementia (15.2%) differed dramatically by patients' pre-fracture residence. One-third of patients admitted from a nursing home had a diagnosis of dementia, compared with 10.6% of those who did not reside in a nursing home at the time of their hip fracture.

The proportion of intertrochanteric femur fracture patients receiving an intramedullary nail device increased from 8.1% in 2000 to 17.1% percent in 2002. The distribution of high risk factors and evidence of care effects did not vary substantially by device (Table 4.2). However, patients with dementia and those admitted from nursing homes comprised a slightly greater proportion of the plate/screw recipients.

Unadjusted mortality

The unadjusted inpatient, 30, 60 and 90-day mortality rates among Medicare intertrochanteric femur fracture patients treated with internal fixation were 2.91%, 7.92%, 12.34% and 15.19% respectively (Table 4.3). The mortality rates among nursing home patients were nearly double those of non-nursing home patients (25.7% vs. 13.5% by 90 days, 2002). The unadjusted mortality rates between intramedullary nail and plate/screw patients were similar.

Hospital and surgeon volume

Between March 1, 2000 and December 31, 2002, 192,365 internal fixation procedures were performed by 15,091 surgeons at 3,480 United States hospitals to treat Medicare intertrochanteric hip fracture patients (Table 4.4). The median number of Medicare intertrochanteric hip fracture surgeries was 10 per surgeon and 41 per hospital during the 34-month period. Nearly 26% of 3,480 case hospitals surgically treated 17 or fewer Medicare intertrochanteric hip fracture patients during the 34-month study period, and these low volume facilities accounted for just under 4% of cases. The highest intertrochanteric fracture volume hospitals (24.7%, n=860, ≥79 cases) treated 56.6% of patients in this study. Hospitals that surgically treated more than the median number of Medicare intertrochanteric fracture patients during the study (42 or more) performed 83.1% of cases. Thirty-four percent of surgeries were performed by the highest volume surgeons (18 or more cases) at the highest volume hospitals (79 or more cases). The joint distribution of surgeries to treat intertrochanteric hip fracture patients by surgeon and hospital volume categories are shown in Table 4.5.

Two-thirds of surgeons performed at least one Medicare intertrochanteric hip fracture surgery in all three study years (65.6%, 9905 of 15,091 surgeons), and these surgeons operated on 88.1% of the patients in this analysis (n=169,438).

Surgeon age and device preference

The median surgeon age was 46 years (mean 47.1 years). Surgeons age 40 or younger performed 29.6% of surgeries for Medicare intertrochanteric fracture patients; 36.4% of procedures were performed by surgeons who were age 50 or older. Among internal fixation procedures, surgeons age 40 or under had the highest rate of intramedullary nail use (16.8% of cases), compared with surgeons age 41-49 (11.9%) and surgeons age 50 and older (8.7%).

Regression results

Patient factors

The regression results in Table 4.6 show the expected relationships between patient factors and mortality, with higher odds ratios of mortality noted with increasing patient age, male gender, white race, increasing comorbidity and nursing home residence[7, 9, 45, 48, 51]. Males had more than twice the odds of mortality than females, particularly inpatient, with a minimal decline in gender differences by ninety days postoperatively. Non-white races had a 20-30% lower likelihood of dying throughout the 90-day postoperative period. After controlling for other model factors, increasing Charlson score had a strong positive association with mortality. Patients with subtrochanteric fractures had higher odds of inpatient mortality (OR=1.21, $p<0.05$), but by 30 days, there were no mortality differences between subtrochanteric and other pertrochanteric fracture patients. Patients who received intramedullary nails had 5.1% higher odds of 90-day mortality than plate-with-screw patients. Patients who received Medicaid-administered assistance and did not reside in a nursing home had nearly 16% higher odds of dying within 90 days of surgery than other non-nursing home patients who were not receiving state-administered assistance. The mortality odds among nursing home patients were substantially higher than non-nursing home patients at all time points, with an abrupt increase noted between inpatient and 30 days following hip surgery that continued to increase but less dramatically from 30 to 90 days from surgery.

Hospital effects

Patients who underwent internal fixation procedures for intertrochanteric hip fractures at hospitals that performed at or below the median number of 41 surgeries during the 34-month study period had significantly higher odds of inpatient mortality than patients whose surgeries were performed at the higher volume hospitals (Table 4.7). After controlling for other patient, surgeon and hospital factors, the odds of inpatient mortality were 7-21% higher among hip fracture patients treated in hospitals that performed 78 or fewer intertrochanteric fracture cases, compared with the highest volume hospitals (79+ cases). From thirty through 90 days post-surgery, the increased mortality odds persisted only among patients treated at the lowest volume hospitals (< 18 cases). There was a linear trend of decreasing mortality odds as hospital volume increased at all time points ($p < 0.05$). There were no significant differences in mortality odds by hospital ownership until 90 days following surgery, when patients treated at for-profit hospitals showed modestly higher (5%) mortality odds than those treated at non-profit facilities. Teaching hospital cases with resident involvement had significantly higher odds of 60 and 90-day mortality, which were not found among non-resident cases treated at teaching hospitals.

Surgeon effects

After controlling for patient and provider factors, patients of surgeons who performed a total of 5-10 intertrochanteric fracture cases during 2000-02 had nearly 10% higher odds of inpatient mortality compared with patients of the highest volume surgeons, which decreased but remained significant throughout 60 days following surgery (Table 4.7). There were no significant mortality differences between patients of the lowest volume surgeons (1-4 cases) compared with patients of surgeons in the highest two volume categories (>10 cases), after controlling for other factors. When compared with patients of surgeons age 50 and older, patients of surgeons age 40 and under had modestly higher odds of mortality at all time points, which reached significance by 90-days post-surgery (OR 1.032, $p=0.046$).

V. Discussion

Hospital effects

The odds of inpatient mortality were significantly higher for intertrochanteric fracture patients having surgery anywhere but the highest volume hospitals, but the increased odds of mortality after hospital discharge persisted only among patients treated at the lowest volume hospitals. Consistent with similar orthopaedic studies of elective arthroplasty procedures[58, 63, 64], we found a decreasing linear trend in mortality as hospitals' intertrochanteric case volume increased. Although comparison of the magnitude of the hospital volume advantage between hip fracture and elective arthroplasty patients from studies with smaller sample sizes was not possible, we found no significant mortality differences after hospital discharge by hospital case volume, except among the lowest volume hospitals.

We are unable to definitely explain the higher mortality found in lower volume hospitals, but unobserved case mix differences are likely despite our efforts to adjust. Hospital volume-outcome studies that use clinical data for risk adjustment are less likely to report significant volume-outcome associations than studies that rely exclusively on administrative data[85]. Also, although not specific to hip fractures, low volume hospitals and surgeons manage sicker patient populations among total hip arthroplasty patients[57]. We observed that low hospital volume was associated with longer delays from admission to surgery, which may be attributable to a lack of on-site orthopaedic surgeon coverage or other operating room staffing and capacity issues. Although other factors may explain this relationship, longer delays to surgery may offer some insights into the mortality-volume relationship.

Differences in mortality among teaching hospitals with and without resident cases were unexpected. Unlike this study, previous work found a significant survival advantage for hip fracture patients treated at major teaching hospitals, although no differentiation between resident and non-resident cases was made[69]. Patient selection differences for cases with resident involvement may be responsible for some of the higher mortality among resident-participation case hospitals, as well as technique-related factors. The degree of resident involvement in cases is not determinable from claims.

Surgeon effects

Intertrochanteric hip fracture patients of surgeons in the second volume quartile (just below the median) had the highest mortality odds inpatient through 60 days following hip surgery, which differs from the low volume findings of elective arthroplasty studies[57, 58, 62-64]. Accordingly, we did not find a decreasing linear trend in mortality as surgeons' volume of intertrochanteric fractures increased. Estimating our models with a different median volume category that encompassed volume both above and below the median (7-15 cases) did not change our mortality findings regarding median volume surgeons. The odds of mortality among patients of surgeons who performed an average of 2-3 intertrochanteric fracture surgeries per year were 5-10% higher than among the highest volume surgeons through 60 days after surgery.

Among the two-thirds of surgeons who operated all three years and treated 88% of cases, the median case volume per surgeon averaged from two to five internal fixation procedures for Medicare intertrochanteric fracture patients per year. Only 12% of surgeries were performed by surgeons who did not surgically treat at least one Medicare intertrochanteric hip fracture patient in each year, 2000 through 2002.

After controlling for patient, device and provider factors, patients of surgeons age 40 and under had minimally (3.2%) but significantly higher odds of 90-day mortality than patients of surgeons age 50 and older. We cannot determine from this analysis if unmeasured patient or other provider factors account for this observed difference.

Patients

Consistent with other study findings, nearly half of all patients in this study were age 85 or older at the time of fracture, making the average Medicare intertrochanteric hip fracture patient older than the average age of elderly femoral neck fracture patients[18, 52, 142, 143]. In addition to higher mortality rates among patients admitted from nursing facilities, we found higher mortality rates by ninety days post-surgery for non-nursing home patients than has previously been reported among elderly hip fracture patients who were not institutionalized at the time of their fracture[7]. The number of patients who fractured their hip while residing in a nursing home is high (20.05%), and this finding is consistent with other U.S. hip fracture studies that included nursing home patients[45, 144]. The unadjusted mortality rates increased annually for both nursing home and non-nursing home patients, although the greatest increase of nearly 3% occurred among nursing home patients. The odds ratios of mortality for nursing home patients increased abruptly between acute inpatient discharge and 30-days following surgery, suggesting that post-acute hip fracture care influences mortality among this high-risk group of elderly patients.

Despite initial optimism regarding the benefits of intramedullary nails on patient outcomes, our bivariate mortality findings by device concur with smaller clinical outcomes studies[28, 39] and meta-analysis conclusions[22] that the mortality rates for intramedullary nail and plate-with-screw patients are similar. The regression findings of significantly higher (5.1%) mortality odds only at 90-days following surgery among patients who received intramedullary nails compared with plate-with-screw patients suggests that even after controlling for comorbidity and nursing home residence, that other factors such as patient selection, provider factors, or residual case-mix differences exist that were not measured in this study.

We acknowledge several limitations that should be kept in mind when interpreting our results. Hospitals' volume of Medicare intertrochanteric fracture patients may not parallel hospital case volume in general. Large, high volume trauma centers may see relatively fewer older patients, so caution is advised in generalization of the hospital volume conclusions. Our study is limited to Medicare fee-for-service patients which may underestimate provider volume in areas where providers treated a large proportion of hip fracture patients enrolled in Medicare managed care plans. However, we note that our surgeon volume conclusions did not change when we altered our median volume range, and previous work has shown that hospital mortality estimates were negligibly affected by the exclusion of high managed care areas[83]. Although this study used only Medicare patient information derived from claims for case selection, excellent concordance has been shown between the Medicare physician and hospital claim files for hip fracture diagnoses and implant; this device validation was reported only for femoral neck fractures where one CPT code is used to report two distinct procedures[105]. Internal fixation surgical procedures for intertrochanteric fractures, in contradistinction to femoral neck fracture procedures, are CPT code-specific to both fracture site and device (27244 and 27245) in the physician claim files, and both diagnosis and ICD-9-CM procedure in the hospital files, which gives enhanced validity to our case determination for this exclusively claims-based study[45, 105]. Additionally, our original case selection from the Centers for Medicare and Medicaid Services limited our cases to those with hip fractures treated by internal fixation. This selection process did not allow for a look-back for previous hip fractures across all fracture types. Despite meticulous data cleaning, we undoubtedly have a small percent of claims from patients who had a previous hip fracture. We acknowledge that the determination of an adapted Charlson score from a single hospital admission without retrospective claims analysis likely underestimates the comorbid illness burden in this population[121, 145]. The pre-fracture nursing home patient identifier was used to account for this look-back deficiency. Additionally, our definition of nursing home residence was inclusive. Some individuals who were in a nursing home for rehabilitation from another condition two months prior to their hip fracture, and were discharged home prior to hip fracture were classified as having been admitted from a nursing home. We did not account for patients who were transferred from other facilities to acute inpatient hospitals for hip fracture surgery, nor hospital-to-hospital transfers. Since our claim look-back duration was consistent with mandatory nursing home patient evaluations, we expect nearly complete identification of individuals who resided in nursing homes at the time of their hip fracture. Despite these apparent limitations, we believe that our results provide valuable information that is not possible to examine in randomized trials, and that our findings offer important insights into the magnitude of the volume-mortality association for elderly hip fracture patients.

Only the highest volume intertrochanteric hip fracture hospitals showed an inpatient mortality benefit in this population-based study of elderly Medicare intertrochanteric hip fracture patients. A hospital volume disadvantage persisted after discharge in only the lowest volume hospitals. Intertrochanteric hip fracture patients treated by surgeons with just below median volume, not the lowest volume surgeons, had the highest odds of short-term postoperative mortality. Our findings highlight possible differences in patient selection for teaching cases with resident involvement, for cases where intramedullary nails are used, and by surgeon age. Additional Medicare studies that examine complications and re-operation rates among resident cases, by the age of the treating surgeon, and by the type of implant used are indicated to see if there is a pattern to the provider and device-related findings for non-mortality endpoints.

Table 4.1: Medicare intertrochanteric hip fracture patients 2000–2002 with type of implant*

Patient Characteristics N=192,365	**2000** n=57,488 (29.88%) % of cases	**2001** n=68,538 (35.63%) % of cases	**2002** n=66,339 (34.49%) % of cases
Age (years)			
65-74	12.07	12.14	12.68
75-84	39.59	39.62	39.09
≥ 85	48.34	48.24	48.23
Sex			
Female	77.92	77.12	76.56
Male	22.08	22.88	23.44
Race			
White	94.83	94.57	94.33
Black	3.13	3.14	3.17
Other	2.03	2.30	2.50
Charlson comorbidity score			
0	49.86	48.99	47.80
1	35.38	35.56	36.13
2	10.89	11.35	11.81
3+	3.86	4.11	4.26
Subtrochanteric fracture			
No	89.85	89.36	89.08
Yes	10.15	10.64	10.92
Residence-state assistance			
Non-nursing home, no state assistance	66.96	68.11	69.57
Nursing home, no state assistance	13.33	12.77	11.52
Non-nursing home, has state assistance	11.51	11.40	12.12
Nursing home, has state assistance	8.20	7.72	6.79
Dementia			
Total	15.41	15.27	14.85
Admitted from nursing facility	33.75	33.47	32.27
Other source of admission	10.38	10.59	10.94
Implant received			
Plate-with-screw	91.92	89.11	82.94
Intramedullary nail	8.08	10.89	17.06

*March 1, 2000 - December 31, 2002

Table 4.2: Distribution of specific risk factors and evidence of care effects by device received among Medicare intertrochanteric hip fracture patients*

	Type of implant	
	Plate/screws n=168,943 (87.82%) % of cases, by device	**Intramedullary nail** n=23,422 (12.18%) % of cases, by device
Evidence of care effects		
Admission to surgery delay: 4 or more days	3.93%	4.53%
Blood units: 4 or more	2.36%	3.08%
Length of stay > 21 days	1.11%	1.38%
Risk factors		
Admitted from a nursing home	20.43%	17.28%
Charlson score: 3 or more	4.05%	4.31%
Dementia	15.34%	13.92%

*March 1, 2000 – December 31, 2002, among non-managed care, internal fixation cases only

Table 4.3: Unadjusted mortality rates among Medicare intertrochanteric hip fracture patients treated with internal fixation March 1, 2000-December 31, 2002

n=192,365	**2000** % of cases	**2001** % of cases	**2002** % of cases
Died inpatient n=5,596			
Total (2.91%)	2.77%	2.94%	3.00%
By pre-fracture residence:			
Admitted from nursing home	3.34%	3.62%	3.76%
Other source of admission	2.62%	2.76%	2.82%
By type of implant:			
Plate-with-screw	2.73%	2.90%	3.00%
Intramedullary nail	3.34%	3.22%	3.00%
Died within 30 days n=15,232			
Total (7.92%)	7.65%	7.85%	8.22%
By pre-fracture residence:			
Admitted from nursing home	11.88%	12.70%	13.39%
Other source of admission	6.50%	6.60%	7.06%
By type of implant:			
Plate-with-screw	7.67%	7.86%	8.25%
Intramedullary nail	7.52%	7.77%	8.08%
Died within 60 days n=23,733			
Total (12.34%)	11.85%	12.30%	12.80%
By pre-fracture residence:			
Admitted from nursing home	18.80%	20.14%	21.08%
Other source of admission	9.94%	10.28%	10.94%
By type of implant:			
Plate-with-screw	11.81%	12.31%	12.79%
Intramedullary nail	12.23%	12.23%	12.84%
Died within 90 days n=29,220			
Total (15.19%)	14.52%	15.19%	15.76%
By pre-fracture residence:			
Admitted from nursing home	22.79%	24.61%	25.67%
Other source of admission	12.26%	12.76%	13.54%
By type of implant:			
Plate-with-screw	14.51%	15.19%	15.72%
Intramedullary nail	14.71%	15.18%	15.99%

*Mortality in days from the hip surgery date on the surgeon's procedure claim. Denominator value is the total number of cases treated with (plate/screws plus intramedullary nails).

Table 4.4: Distribution of Medicare intertrochanteric hip fracture providers by volume quartiles March 1, 2000 through December 31, 2002

Provider case volume*	Provider frequency	Percent of providers	Percent of cases n=192,365	Approximate number of cases per year**
Hospitals median=41				
1-17	893	25.66	3.99	0-6
18-41	859	24.68	12.88	7-14
42-78	868	24.95	26.49	15-27
79+	860	24.71	56.64	28+
Total hospitals	3,480	100.0	100.0	
Surgeons median=10				
1 - 4	3715	24.62	4.48	0-1
5 - 10	3999	26.50	15.32	2-3
11 - 17	3446	22.83	24.67	4-6
18+	3931	26.05	55.53	7+
Total surgeons	15,091	100.0	100.0	

* Calculated case volume per provider for Medicare patients age 65 or older, not in managed care

** Estimated cases per year as the total number of provider cases averaged over the 34-month study period

Table 4.5: Distribution of Medicare internal fixation intertrochanteric fracture cases by provider type and case volume quartile, March 1, 2000 through December 31, 2002

Hospital volume*	Surgeon volume*				
	1-4	**5-10**	**11-17**	**18+**	**Total**
1-17	0.50	1.16	1.11	1.21	3.99%
18-41	0.86	2.46	3.47	6.09	12.88%
42-78	1.25	4.43	7.08	13.74	26.49%
79+	1.87	7.26	13.02	34.49	56.64%
Total	4.48%	15.32%	24.67%	55.53%	100%

*Median hospital volume: 41 cases; median surgeon volume: 10 cases. Total cases =192,365

Table 4.6: Patient factors, device and year: adjusted odds ratios of mortality inpatient through 90 days following intertrochanteric hip fracture surgery

N=192,365	**Inpatient** n=5,596 (2.91%)	**30 days** n=15,232 (7.92%)	**60 days** n=23,733 (12.34%)	**90 days** n=29,220 (15.19%)
Age (years)				
65-74*	1.00	1.00	1.00	1.00
75-84	**1.396**	**1.613**	**1.643**	**1.655**
85 or older	**2.320**	**2.973**	**3.119**	**3.162**
Sex				
Female*	1.00	1.00	1.00	1.00
Male	**2.200**	**2.058**	**1.945**	**1.909**
Race				
White*	1.00	1.00	1.00	1.00
Black	0.859	**0.722**	**0.776**	**0.817**
Other	0.824	**0.762**	**0.700**	**0.713**
Charlson score				
0*	1.00	1.00	1.00	1.00
1	**1.155**	**1.380**	**1.432**	**1.441**
2	**1.452**	**1.660**	**1.700**	**1.731**
3+	**1.942**	**2.221**	**2.428**	**2.526**
Subtrochanteric fracture				
No *	1.00	1.00	1.00	1.00
Yes	**1.205**	1.058	1.012	0.987
Nursing home-state Medicaid assistance				
Not from nursing home, no state assistance*	1.00	1.00	1.00	1.00
From nursing home, no state assistance	**1.263**	**1.866**	**1.990**	**2.015**
Not from nursing home, has state assistance	1.060	**1.090**	**1.139**	**1.155**
From nursing home, has state assistance	**1.148**	**1.716**	**1.865**	**1.893**
Type of implant				
Intramedullary nail	1.061	1.005	1.042	**1.051**
Plate-with-screw	1.00	1.00	1.00	1.00
Year				
2000	0.941	**0.919**	**0.908**	**0.901**
2001	0.988	**0.942**	**0.947**	**0.949**
2002*	1.00	1.00	1.00	1.00

*Controlling for the provider factors in Table 4.7
Bold value indicates p value for the odds ratio of $p < 0.05$.

Table 4.7: Hospital and surgeon factors: adjusted odds ratios of mortality inpatient through 90 days following intertrochanteric hip fracture surgery among elderly Medicare patients

Provider variable	**Odds ratios of postoperative mortality**			
	Inpatient n=5,596 (2.91%)	**30 days** n=15,232 (7.92%)	**60 days** n=23,733 (12.34%)	**90 days** n=29,220 (15.19%)
Hospital case volume**				
1-17	**1.212**	**1.129**	**1.088**	**1.082**
18-41 (median=41)	**1.119**	1.052	1.035	1.002
42-78	1.072	1.028	1.020	1.019
79+*	1.00	ref	ref	ref
Hospital teaching status				
Non-teaching*	1.00	ref	ref	ref
Teaching	1.022	0.978	0.999	0.995
Teaching/resident on case	0.959	1.032	**1.114**	**1.140**
Hospital ownership				
Not for profit*	1.00	ref	ref	ref
For profit	0.928	0.992	1.045	**1.053**
Government	1.072	1.006	1.007	1.012
Surgeon case volume**				
1 – 4	0.933	0.941	0.970	0.995
5 – 10 (median=10)	**1.098**	**1.075**	**1.052**	1.028
11 – 17	0.996	1.035	1.028	1.018
18 or more*	1.00	ref	ref	ref
Surgeon age (years)				
<= age 40	1.019	1.025	1.023	**1.032**
age 41-49	0.964	1.004	1.002	0.995
age 50+	1.00	1.00	1.00	1.00

*Odds ratios for each predictor variable are compared with the category reference level (OR=1.00).

Bold value indicates p value for the odds ratio of $p < 0.05$.

Controlling for all Table 4.6 factors: age, sex, race, Charlson comorbidity score, subtrochanteric fracture, nursing home residence, Medicaid-administered assistance, device and year

**Volume calculations are based on the total number of elderly Medicare intertrochanteric fracture patients treated with internal fixation per provider between March 1, 2000 and December 31, 2002

CHAPTER 5: SUMMARY

Since 1992, Medicare has paid surgeons more to use IMN than plate/screws procedures in the treatment of intertrochanteric hip fracture patients. In contrast, Medicare pays hospitals under the same DRGs for both the IMN and plate/screws procedures, although the IMN implants cost hospitals up to $1000 more per device than plate/screws. Thus, Medicare has generated competing payment incentives between surgeons and hospitals in the treatment of intertrochanteric hip fracture patients. The effect of this ongoing provider payment difference on IMN use among Medicare hip fracture patients has not previously been examined.

Despite equivalent clinical outcomes for most IMN and plate/screws intertrochanteric hip fracture patients[22, 23], IMN use in the United States has continued to increase and is now the dominant mode of internal fixation for intertrochanteric hip fracture treatment[34, 36, 37, 146]. Although our study found that on average, only 17% of Medicare intertrochanteric hip fracture patients were treated with IMN in 2002, by 2004, IMN use had more than doubled to 36% of internal fixation cases[37, 146]. By 2005, IMN use among the same Medicare patient group had risen to more than 47% of cases, and is now estimated to comprise more than 60% of internal fixation implants used to treat intertrochanteric hip fracture patients in the United States[34, 36, 147].

Given the increasing proportion of the U.S. population that is becoming elderly and Medicare-eligible, the utilization of high-value, cost-effective treatments for geriatric patients is one of the main goals of the Medicare program[17]. The optimal treatment of geriatric hip fracture patients therefore aims to maximize functional recovery while minimizing complications and treatment costs for this serious, common and disabling condition among Medicare beneficiaries.

The preceding series of papers examined the patient, surgeon and hospital factors that were associated with surgical procedure variation and mortality in the treatment of intertrochanteric hip fracture patients in Medicare during 2000 through 2002.

Manuscript 1

The first paper assessed the degree of geographic variation in the use of intramedullary nails (IMN) for intertrochanteric hip fracture treatment in elderly United States Medicare beneficiaries from 2000 through 2002. IMN use was modeled as a function of state and year, with and without adjustment for multiple patient-related factors.

We found considerable geographic variation in IMN use by state across all years. IMN use in Medicare intertrochanteric hip fracture patients more than doubled nationally from 8% in 2000 to 17% of internal fixation procedures in 2002. By 2002, surgeons in only two states used an IMN in less than one of every 20 patients with an intertrochanteric fracture, and in eight states they used an IMN in more than one of every 4 patients.

Consistent with the orthopaedic literature, we found significantly higher odds of IMN use among patients with unstable subtrochanteric fractures, compared to other intertrochanteric hip fractures. We found higher odds of IMN use among blacks, younger patients, males and patients on Medicaid-administered assistance, which we were unable to explain by any plausible differences in clinical factors among those patients.

Our findings support our hypotheses that geographic variation in IMN use from 2000-2002 was extensive, that it was largely not explained by patient factors, and that the observed surgeon practice patterns persisted over time. Although controlling for patient factors significantly improved the fit of our models, the predicted probabilities of IMN use by state essentially did not change when multiple patient factors were added to the models. We therefore concluded that other, non-patient factors were responsible for the significant variation that was noted in IMN use, and sought to examine the associated provider factors in the second paper.

Manuscript 2

The goal of the second paper was to identify the surgeon and hospital factors that were associated with high IMN use among Medicare intertrochanteric hip fracture patients treated with internal fixation. We used mixed models with fixed and random effects to model the association between surgeon and hospital factors, and the dichotomous outcome of device choice (IMN or plate/screws), while including patient factors.

Surgeon factors, more than hospital factors, accounted for the observed variation in IMN use. Early-career surgeons, orthopaedic faculty who supervised resident operative cases, surgeons in high volume or teaching hospitals, surgeons who operated at more than one hospital and doctors of osteopathy were more likely to choose IMN than older surgeons, surgeons who operated at only one hospital, non-teaching surgeons and hospitals, and MD-degreed surgeons during 2000 through 2002.

Despite talk about evidence-based medicine, it appears that orthopaedic faculty at teaching institutions, surgeons at high-volume hospitals and younger surgeons are selecting orthopaedic implants that are more expensive but not more effective. Ironically, both younger surgeons and teaching surgeons who have greater understanding of evidence-based medicine principles than older and non-teaching surgeons[148] were found to be the surgeon groups who were most likely to select IMN implants in this study.

Manuscript 3

The third paper examined the association between surgeon and hospital volumes of Medicare intertrochanteric hip fracture surgeries and inpatient through 90-day mortality, after controlling for device, patient and other hospital and surgeon factors. We hypothesized that patients treated in low volume hospitals or by low volume surgeons would have higher short-term mortality risks than high volume providers. Fixed effects regression analysis using generalized estimating equations accounted for the similarities among patients treated within the same hospital.

Our device findings concur with smaller clinical outcomes studies[28, 39] and meta-analysis conclusions[22] that the mortality rates for intramedullary nail and plate/screw patients are similar. Hence, IMN showed no quality advantage over plate/screws procedures when mortality was the outcome.

However, the volume-mortality findings for non-elective Medicare hip fracture patients differed from the results reported for elective arthroplasty studies in several ways.

For hospitals, our results are consistent with the general direction of the volume-outcomes conclusions found in elective arthroplasty studies, but the magnitude of the positive volume effect was smaller among hip fracture patients. We found a decreasing linear trend in mortality odds as hospitals' intertrochanteric case volume increased, however this trend was significant only during inpatient stays. Following hospital discharge, the 8-13% higher adjusted mortality odds persisted through 90-days postoperatively only among patients treated in the lowest volume hospitals (average ≤ 6 intertrochanteric hip fractures per year).

For surgeons, our results are not consistent with the high volume mortality advantages found among elective arthroplasty Medicare patients of high-volume surgeons. Instead, we found no significant mortality differences among patients of the lowest compared with the highest volume hip fracture surgeons, but rather, 5-10% higher adjusted mortality odds among patients of mid-volume surgeons (average 2-3 cases per year) compared with the highest volume hip fracture surgeons inpatient through 60-days post-surgery. By 90-days, there were no significant differences in patients' adjusted mortality odds based on surgeon volume.

We found longer delays from admission to surgery in lower volume hospitals, which may explain some of the higher mortality observed in patients treated in low volume facilities. A lack of on-site orthopaedic surgeon coverage and other staffing or operating room capacity issues may account for the longer delays noted. A lack of standardized perioperative and postoperative treatment protocols or other unobserved case mix differences may also contribute to higher inpatient through 90-day mortality among patients treated in low volume hospitals.

Contrary to the volume-outcomes conclusions of elective arthroplasty studies, our findings do not support the need for directing elderly Medicare hip fracture patients exclusively to high volume surgeons nor hospitals. However, further investigation into the sources of the higher mortality odds and longer admission to surgery delays in low volume hospitals is warranted.

Discussion

Significant variation in surgical treatments for intertrochanteric hip fracture patients highlights some degree of professional disagreement or uncertainty as to which procedure, IMN or plate/screws, is optimal under various clinical situations. Professional disagreement may result from either a lack of outcomes information or from varying levels of clinical application of existing outcomes information. Surgical procedure variation provides an opportunity to identify the patient and non-patient factors that account for the utilization patterns observed, which enables further study of the provider and patient subgroups that have particularly high variation in specific procedure utilization, clinical outcomes or both.

Patient factors largely did not account for the wide geographic variation noted in IMN use among Medicare intertrochanteric hip fracture patients in 2000 through 2002. When provider factors were added to our models, surgeon factors predicted device choice more than hospital factors, which makes sense given that surgeons decide both the procedure and implant for their patients, while hospitals can only make access to devices either easier or harder based on their purchasing choices.

If not driven by clinical outcomes evidence then, IMN use has likely been influenced by other factors that have resulted in high levels of IMN use among subsets of orthopaedic surgeons. Only certain segments of the orthopaedic surgeon professional community chose to use IMN during this 2000-2002 study, which covers three years at the end of the decade that followed Medicare's 1992 differential CPT-coding and payment of IMN and plate/screws procedures for intertrochanteric hip fracture treatment.

Several factors may account for the IMN-related practice patterns that we observed. Taken together, our results highlight two main influences on surgeons that resulted in the IMN use patterns we observed: training and payment.

Training effects

Contrary to the general surgical technology adoption literature[65] and our hypothesis, we found the highest IMN use among the youngest group of orthopaedic surgeons, rather than mid-career, experienced surgeons. These observed differences may be due to the timing of our study. Although our study is limited to the reporting of associations, resident-supervising surgeons in teaching hospitals had to first adopt the newer IMN procedures in order to train and direct trainee surgeons to use them, which suggests that our study identifies patterns during mid-diffusion of the IMN procedures for hip fracture treatment. The collective associations between high IMN use and teaching hospitals, orthopaedic resident cases, and younger surgeons strongly suggests that the procedures surgeons learn during training are the procedures that they will continue to use in their post-graduation orthopaedic practice, since orthopaedic surgical residency training is entirely dependent upon mentoring by academic surgeons.

What remains unclear then, was and continues to be the rationale of academic surgeons to recommend IMN when outcomes evidence suggests that a less costly procedure would give similar outcomes in most cases.

Surgeons' perceptions about the additional benefits of a new procedure on clinical outcomes, their desire to keep up state-of-the-art techniques, and to a lesser extent, the technical aspects of surgical procedures are important factors in new procedure adoption decisions[149-151]. In the case of IMN, hopes of improved outcomes may have outweighed the clinical outcomes evidence that concluded equivalency between the procedures, at least among academic and younger surgeons.

In the absence of convincing outcomes evidence to support high IMN use, the strongest adoption influences that affect trainee surgeons may come from the orthopaedic device manufacturers' efforts within teaching hospitals. High-prestige, academic surgeons are likely targeted by device companies seeking opinion leaders and influential resident-mentors to support the use of new implants aimed at improving outcomes. Therefore, high-profile, academic surgeons as device company consultants provide the greatest marketing exposure to new technology than any other surgeon subset. Much like the tobacco industry, orthopaedic device manufacturers need to get younger surgeons to use newer products in training to best assure continued use after graduation, since older surgeons are less likely to adopt new technology[65]. The only way to do so is to recruit academic-ranked surgeons whose opinions are influential as to which implants and procedures should be utilized within surgeon training programs and teaching hospitals.

High-paying consulting arrangements are one way of infusing bias into the decisions of any surgeon, but potentially have far greater effects when the marketing targets are academic orthopaedic surgeons and orthopaedic department chairmen.

Although not limited to academic surgeons, such consulting arrangements have come under great legal scrutiny within the last several years, and have resulted in the public reporting of both the nature and amount of orthopaedic surgeons' consulting arrangements with orthopaedic implant manufacturers for total joint replacement products[152, 153].

Thus, teaching surgeons who also serve as device company consultants have an economic incentive to use IMN from both the implant manufacturers and to a lesser degree, by Medicare. They will in turn, influence surgeons-in-training, who will likely continue these practice patterns after completion of their orthopaedic residency program.

Payment effects

Medicare's continuing higher payments to surgeons for IMN over plate/screws procedures affects all surgeons, but the payment incentive did not affect the choices of all surgeons during 2000-2002.

Higher IMN procedure payments appear to have had the greatest influence on early-career surgeons who, in addition to growing their skills and increasing their practice base, were eager to earn money. Therefore, the decisions of the youngest group of surgeons were most likely influenced toward IMN by both preferential training in IMN use during residency, and higher Medicare payments for IMN procedures following graduation. Higher Medicare IMN reimbursement likely encouraged the high IMN use noted among multi-hospital surgeons who were seeking to maximize their income by taking call at other hospitals.

For surgeons who were not trained as residents with IMN, higher IMN procedure payments combined with sufficient hip fracture case volume provided an incentive to learn to apply IMN technology to hip fractures, since most surgeons were familiar with similar IMN implants for fractures at other body sites. Once surgeons started to use IMN for hip fractures, higher Medicare payments acted to reinforce IMN use.

Since the year 2000, IMN use among Medicare intertrochanteric hip fracture patients has increased almost 10-fold. This pattern developed subsequent to a Medicare RVU payment incentive for IMN procedures, and as of 2008, a 6.48 RVU incentive remains (about $220) [154]. In the face of such a payment incentive, we do not believe that increased information on comparative effectiveness of the devices would change the current physician practice patterns.

The orthopaedic literature commonly mentions the higher costs of the IMN devices[29, 32, 39] so we do not believe that surgeons lack device cost information in their implant decision-making. However, although common in the economic literature, the orthopaedic literature only recently began publishing articles and editorial discussions that included the possibility that higher Medicare payments to surgeons for IMN procedures may be one of the factors driving the substantial increases in IMN use for intertrochanteric hip fracture treatment in the United States[34, 101, 106, 155].

Other influences

Other factors may have amplified the training and payment effects that resulted in the surgeon-IMN use patterns we observed. Once mastered, surgeons may find IMN procedures easier and faster to perform than plate/screws. Surgeons may also find IMN more clinically appealing than plate/screws procedures due to the smaller surgical exposure required to place the implant, and less associated blood loss. High IMN use among young surgeons suggests that some surgeons may perceive IMN to be technically more forgiving of technique imperfections, theoretically providing a more stable construct for fracture healing in cases where their fracture re-alignment (*reduction*) may be nonanatomic, and/or the implant placement is suboptimal.

Surgeons may have assumed that device modifications made subsequent to 1998 resolved the higher complication rates that plagued the first-generation IMN devices, particularly iatrogenic intraoperative fractures and postoperative femoral shaft fractures[22, 23, 34]. Although several randomized clinical trials are in progress, we are not aware of literature that supports improved outcomes with the second- and third-generation devices. Also, many of the surgeries performed in the randomized clinical trials (RCTs) were performed by orthopaedic residents, and surgeons may have assumed that IMN complications were less common when IMN was used by experienced orthopaedic surgeons.

The exposure to various forms of IMN information, along with heavy industry marketing at orthopaedic meetings and by in-hospital manufacturer's representatives, may also affect surgeons' decisions, especially among surgeons with insufficient time or training to critically evaluate outcomes evidence. We would expect that older surgeons who may lack training in evidence interpretation would be more susceptible to marketing claims and literature misinterpretation than younger surgeons. Also, high-volume surgeons who are competent in evidence appraisal may instead choose to rely on industry information due to time constraints, which may result in a more favorable assessment of the value of a device than outcomes evidence would support[156].

Additionally, significant disagreement exists among orthopaedic surgeons as to which fracture patterns should be considered as *unstable,* and may therefore warrant an IMN rather than plate/screws device based on clinical outcomes studies. Within the AO/OTA fracture classification system[157], there are 9 patterns of pertrochanteric fractures. However, there is no consensus among surgeons about how to dichotomize the classifications into stable and unstable patterns. Thus, there is no consistency in the stable versus unstable grouping of fractures within the existing RCTs, particularly among fractures in the mid-range of intertrochanteric fracture classifications (OA/OTA 31-A2 subtypes). Both in RCTs and clinical practice, surgeon's decision to label fractures as 'unstable' relaxes the clinical criteria necessary to justify their selection of an IMN device with outcomes information that incorrectly assumes consistency in the stable/unstable fracture distinction across outcomes studies.

Hospital incentives

Higher use of IMN within high-volume and teaching hospitals is consistent with the general medical technology adoption literature in that these facilities tend to be earlier adopters[102]. Also, prior adoption of newer technology by another surgeon in the same hospital has been shown to expedite the adoption by other surgeons in the same hospital[102]. Our findings of high IMN use in teaching and high-volume hospitals suggest that hospitals do not find the additional IMN device costs prohibitive under Medicare DRGs, and that the actual additional costs of the IMN devices in teaching and high volume hospitals may be buffered by factors such as volume discounting. Other than higher IMN device costs, utilization of the IMN surgical procedures did not require hospitals' investment in new imaging nor operating room technology.

Summary

Device choice for Medicare intertrochanteric hip fracture patients was not based primarily on patient factors in 2000-2002. Device choice was and continues to be driven by factors other than substantial clinical outcomes evidence, particularly within certain subsets of providers. Surgeon more than hospital factors accounted for high IMN use. IMN procedure choices made in one segment of the provider group did not remain isolated within that segment, but were passed along via training to other provider subsets. We find it interesting that both the orthopaedic faculty involved in the training of new surgeons and early-career surgeons who are taught evidence-based medicine principles would be the providers we observed to have the highest IMN use over a 3-year period.

In addition to preferential training, higher Medicare reimbursement to surgeons for IMN is likely contributing to substantial increases in IMN use when a less-expensive procedure would give similar outcomes in the majority of cases. Subsequent to an RVU payment incentive, IMN use has increased dramatically, yet this increased IMN use has resulted in no better quality for most patients and at a higher cost to both hospitals and Medicare. We expect that IMN use will continue to increase as long as an IMN payment incentive remains and new surgeons are preferentially trained in IMN.

Contribution to scientific knowledge

This work contributes to the body of scientific knowledge in three main areas: the technology adoption patterns of orthopaedic surgeons, surgeons' response to ongoing Medicare procedure payment differences, and the effects of provider volume on mortality among Medicare hip fracture patients. We are not aware of other studies that have looked at geographic variation and provider patterns in device use among Medicare intertrochanteric hip fracture patients. Although many studies have examined hip fracture patient characteristics in procedure outcomes, we are unaware of other studies that have collectively examined both the provider and patient factors that were associated with hip fracture procedures, nor the association between provider factors and early mortality following intertrochanteric hip fracture in a large, population-based study of Medicare patients. The associations between IMN use and younger surgeons and orthopaedic residents were particularly enlightening as to the strong effect of training on subsequent IMN use. Contrary to our hypothesis, surgeon case volume was not a driver of IMN use, but hospital volume was. We found less of a hospital volume benefit on mortality among hip fracture patients than has been observed among elective arthroplasty patients.

Research recommendations

Further investigation is necessary to determine if these provider-IMN use patterns affect non-mortality outcomes after intertrochanteric hip fracture surgeries in Medicare patients, such as revision surgery, implant failure and other postoperative complications such as infection and implant-related fracture. Although this series of papers provides an in-depth evaluation of device use patterns for two orthopaedic procedures that have similar outcomes but are paid at different rates, similar provider patterns likely exist for surgical procedures in other specialties that have similar outcomes and reimbursement patterns.

Additional investigation into the sources of the higher mortality and longer admission to surgery delays in low volume hospitals is warranted to determine if improvements in inpatient through 90-day mortality outcomes can be made.

Since IMN procedures are paid by CMS as requiring more surgeon work, we recommend a study of Medicare claims to examine differences in operating room times, blood units transfused, and hospital lengths of stay to determine if IMN provides a perioperative advantage over plate/screws, after controlling for patient and provider factors.

Although an internal validation of Medicare hip fracture claims across provider data files has been performed, we recommend an external validation study that compares hip fracture patient and provider factors determined from the Medicare claims and enrollment files with in-patient hospital records and licensing board registries.

A survey of orthopaedic surgeons is recommended to better understand their technology adoption rationale. Given that most of the technology adoption literature for surgeons pre-dates evidence-based medicine, such a survey seems particularly timely to assess what impact, if any, outcomes evidence has had on the surgeon technology adoption patterns identified by older adoption studies.

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Appendix A:

Case selection process for Medicare intertrochanteric femur fractures

Physician Claims Files (Carrier) 2000-2002

Select on:

1. One of two Current Procedural Terminology (CPT) codes from the physician claim files[158]:

27244: treatment of inter/per/subtrochanteric femoral fracture; with plate/screw type implant,

or

27245: treatment of inter/per/subtrochanteric femoral fracture; with intramedullary implant

and

2. One of the following line ICD-9-CM diagnosis codes[159]:

820.2	pertrochanteric fracture, closed
820.20	closed fracture, trochanteric section, unspecified
820.21	closed fracture, intertrochanteric section
820.22	closed fracture, subtrochanteric section
820.3	pertrochanteric fracture, open
820.30	open fracture, trochanteric section, unspecified
820.31	open fracture, intertrochanteric section
820.32	open fracture, subtrochanteric section
820.8	unspecified part of neck of femur, closed
820.9	unspecified part of neck of femur, open

From those cases, exclude the following:

- denied claims
- denied line items
- claims paid to physicians assistants
- provider facility (surgeon's) state code outside of the 50 United States or District of Columbia
- cases with procedure code modifiers (either modifier field):
  - -50: bilateral procedure
  - -53: discontinued procedure
  - -55: postoperative management only
  - -56: preoperative management only
  - -58: staged or related procedure by same surgeon during the postoperative period
  - -62: two surgeons
  - -78: return to operating room for related procedure during the postoperative period
  - -79: unrelated procedure by the same surgeon during the postoperative period
  - -80: assistant surgeon
  - -81: minimal assistant surgeon
  - -82: assistant surgeon when qualified resident surgeon not available
  - -AS: physicians assistant claim

3. For each patient: If more than one hip surgery date met selection criteria, we kept only the physician claim for the first (earliest) hip surgery date.

Beneficiary Enrollment Files (Denominator) 2000-2002

Exclude the following:

- race listed as *unknown*
- patients with any managed care enrollment
- Medicare status code 20,21,31 (non-elderly disabled (or not) with or without ESRD)
- non-United States residents

Hospital Claims Files (MedPAR) 2000-2002

Select on:
One of two ICD-9-CM procedure codes from the hospital file[160]:

79.15 closed reduction of femur fracture with internal fixation, **or**
79.35 open reduction of femur fracture with internal fixation

and

2. One of the following line ICD-9 diagnosis codes: limit to fractures of the proximal femur[159]:

820.2 pertrochanteric fracture, closed
820.20 closed fracture, trochanteric section, unspecified
820.21 closed fracture, intertrochanteric section
820.22 closed fracture, subtrochanteric section
820.3 pertrochanteric fracture, open
820.30 open fracture, trochanteric section, unspecified
820.31 open fracture, intertrochanteric section
820.32 open fracture, subtrochanteric section
820.8 unspecified part of neck of femur, closed
820.9 unspecified part of neck of femur, open

Case exclusions:

Exclude claim if any of the following diagnoses are present, any diagnosis field (1-10):

- Osteomyelitis:
  730.0 Osteomyelitis, unspecified site
  730.00 Acute osteomyelitis, unspecified site
  730.05 Acute osteomyelitis, pelvic region and thigh
  730.10 Chronic osteomyelitis, unspecified site
  730.15 Chronic osteomyelitis, pelvic region and thigh
  730.20 Unspecified osteomyelitis, unspecified site
  730.25 Unspecified osteomyelitis, pelvic region and thigh
  730.30 Periostitis without mention of osteomyelitis, unspecified site
  730.35 Periostitis without mention of osteomyelitis, pelvic region and thigh
  730.90 Unspecified infection of bone, unspecified site
  730.95 Unspecified infection of bone, pelvic region and thigh
- Pathologic fracture: delete only if accompanied by a cancer-related or V10 code, or if not accompanied by an osteoporosis code (see Neoplasms below):
  733.1 Pathologic fracture
  733.10 Pathologic fracture, unspecified site
  733.14 Pathologic fracture of neck of femur
  733.15 Pathologic fracture of other specified part of femur
- Avascular necrosis:

733.4 Aseptic necrosis of bone
733.40 Aseptic necrosis of bone, unspecified site
733.42 Aseptic necrosis of bone, head and neck of femur
733.49 Aseptic necrosis of bone, other

- Malunion and nonunion of fracture:
  733.8 Malunion and non-union of fracture
  733.81 Malunion of fracture
  733.82 Nonunion of fracture
- Pelvis and/or multiple lower extremity fractures:
  808.0 Fractures of acetabulum closed
  808.1 Fractures of acetabulum, open
  808.2 Pubis, closed
  808.3 Pubis, open
  808.4 Other pelvis, closed
  808.4x Other specified fracture of pelvis, closed
  808.5x Other specified fracture of pelvis, open
  808.8 Unspecified fracture of pelvis, closed
  808.9 Unspecified fracture of pelvis, open
  827.0 Other multiple and ill-defined fractures of lower limb, closed
  827.1 Other multiple and ill-defined fractures of lower limb, open
  828.0 Multiple fractures involving both lower limbs, closed
  828.1 Multiple fractures involving both lower limbs, open
- Late-effects of musculoskeletal and connective tissue injuries:
  905.3 Late effect of fracture of neck of femur
  905.4 Late effect of lower extremity fracture
  905.5 Late effect of fracture of multiple and unspecified bones
- Mechanical complication of internal orthopedic device, implant, and graft:
  996.4 Mechanical complication of internal orthopedic device, implant, and graft
- Infection and inflammatory reaction due to internal prosthetic device, implant, and graft
  996.60 Due to unspecified device, implant, and graft
  996.67 Due to internal orthopedic device, implant, and graft
- Device complications: other complications of internal prosthetic device, implant, and graft
  996.70 Due to unspecified device, implant, and graft
  996.78 Due to other internal orthopedic device, implant, graft
- Postoperative infection:
  998.59 Other postoperative infection
- Other specified complications of procedures, not elsewhere classified:
  998.83 Non-healing surgical wound
  998.89 Other specified complications
  998.9 Unspecified complication of procedure, not elsewhere classified
- Aftercare and rehabilitation:
  V53.7 Fitting and adjustment of orthopedic device
  V54.0x Aftercare involving internal fixation device
  V54.13 Aftercare for healing traumatic fracture of hip
  V54.14 Aftercare for healing traumatic fracture of leg, unspecified
  V54.15 Aftercare for healing traumatic fracture of upper leg
  V54.16 Aftercare for healing traumatic fracture of lower leg
  V54.17 Aftercare for healing traumatic fracture of vertebrae

V54.19 Aftercare for healing traumatic fracture of other bone
V54.2x Aftercare for healing pathologic fracture
V54.8x Other orthopedic aftercare
V54.9 Unspecified orthopedic aftercare
V57.89 Other specified rehabilitation procedure, other
V58.43 Aftercare following surgery for injury and trauma
V58.49 Other specified aftercare following surgery

- Evidence of high-energy trauma involving train, motor vehicle, bicycle, pedestrian hit, off-road vehicle, snow vehicle, animal riding, other:
  E810 through E823, and E825 through E829
- Neoplasms:
  170.6 Malignant neoplasm of pelvic bones, sacrum and coccyx
  170.7 Malignant neoplasm of long bones of lower limb
  170.9 Malignant neoplasm of bone and articular cartilage, site unspecified
  195.x Malignant neoplasm of other and ill-defined sites
  198.5 Secondary malignant neoplasm of bone and bone marrow
  196.x Secondary and unspecified malignant neoplasm of lymph nodes
  197.x Secondary malignant neoplasm of respiratory and digestive systems
  198.x Secondary malignant neoplasm of other specified sites
  199.0 Malignant neoplasm without specification of site, disseminated
  199.1 Malignant neoplasm without specification of site, other
  200.x Lymphosarcoma and reticulosarcoma
  201.x Hodgkin's disease
  202.x Other malignant neoplasms of lymphoid and histiocytic tissue
  203.xx Multiple myeloma and immunoproliferative neoplasms
  204.xx Lymphoid leukemia
  205.xx Myeloid leukemia
  206.xx Monocytic leukemia
  207.xx Other specified leukemia
  208.xx Leukemia of unspecified cell type
  213.6 Benign neoplasm of pelvic bones, sacrum and coccyx
  213.7 Benign neoplasm of long bones of lower limb
  213.9 Benign neoplasm of bone and articular cartilage, site unspecified
  238.0 Neoplasm of uncertain behavior, bone and articular cartilage
  239.2 Neoplasm of unspecified nature of bone, soft tissue and skin
  V10.81 Personal history of malignant neoplasm of bone

Additional notes on patients with cancer-related diagnosis codes:

- We excluded cases coded as having a *pathologic fracture* if there was any accompanying neoplasm or history of cancer code (V10.xx).
  -From the remaining claims, we excluded cases coded as having a *pathologic fracture* without an accompanying *osteoporosis* code on the claim.
  {We therefore included cases with a *pathologic fracture* code only if there was an accompanying *osteoporosis* code (733.0x) and no neoplasm or history of cancer (V10.xx) code.}
- Following the above case exclusions, we divided the remaining cases with any MedPAR ICD-9 cancer-related code(s) into 3 categories (none were listed as having pathologic fractures):
  1. cases with any one of five cancers that most commonly metastasize to bone:

thyroid, breast, prostate, kidney or lung
2. cases with other cancers, not previously excluded
3. cases with a V10.x code only, other than V10.81 (previously excluded)

-If a claim had both a V10 and an ICD-9 cancer code (#1 or #2 above), the patient was categorized in the appropriate cancer category.
-If a claim had both types of cancer codes (#1 and #2), they were included in category #1 above.

We added these remaining cases with a cancer-related diagnoses (categories #1-#3 above) as three dummy-coded predictors in logistic regression, modeling intramedullary nail use (0/1) as a function of state, year, and the other standard patient predictors. None of the coefficients on the above 3 cancer-related predictors were significant for device; therefore we <u>included</u> these patients in our analysis.

Final steps: (all patients had a CPT procedure code of 27244 or 27245):

- Merged files, first by year (Carrier+MedPAR+enrollment), then all 3 years together
- Kept the first hip surgery date by patient identifier across all 3 years
- Limited cases to a diagnosis and procedure date match (MedPAR and Carrier files) within a +/- 7 day window around the Carrier hip surgery date
- Limited cases to Medicare (Parts A+B enrollment) or (Parts A+B with Medicaid-administered assistance) during the hospital stay of interest
- Calculated patient age on the date of surgery using the hip surgery date from the Carrier claim and each patient's date of birth listed in the enrollment file. Kept cases if age was 65 or greater on the date of surgery.

Appendix B: 2000 Adjusted odds ratios and rates of intramedullary nail use for intertrochanteric fractures

State	**Adjusted odds ratio**[1] compared to Wyoming	**95% confidence interval for odds ratio**	**Adjusted IMN rate**[1,2]
Alabama	0.704	0.350 - 1.416	5.62
Alaska	0.222	0.027 - 1.811	1.96
Arizona	2.339	1.179 - 4.639	14.86
Arkansas	0.656	0.319 - 1.349	4.97
California	1.475	0.756 - 2.877	10.36
Colorado	1.316	0.645 - 2.687	8.97
Connecticut	0.872	0.429 - 1.773	6.07
Delaware	1.028	0.444 - 2.378	7.08
District of Columbia	0.647	0.189 - 2.217	6.06
Florida	1.928	0.991 - 3.752	12.20
Georgia	0.750	0.377 - 1.492	5.75
Hawaii	0.422	0.136 - 1.307	4.00
Idaho	1.068	0.479 - 2.379	7.42
Illinois	2.139	1.096 - 4.172	13.21
Indiana	1.013	0.512 - 2.003	7.14
Iowa	0.363	0.173 - 0.760	2.76
Kansas	1.011	0.500 - 2.047	7.43
Kentucky	0.792	0.392 - 1.598	5.57
Louisiana	0.509	0.245 - 1.059	3.89
Maine	0.463	0.205 - 1.044	3.59
Maryland	0.930	0.463 - 1.867	6.94
Massachusetts	0.532	0.264 - 1.074	3.81
Michigan	1.292	0.659 - 2.533	8.91
Minnesota	0.720	0.355 - 1.459	5.48
Mississippi	0.646	0.311 - 1.341	5.22
Missouri	0.908	0.458 - 1.800	6.35
Montana	2.835	1.368 - 5.874	17.05
Nebraska	1.257	0.612 - 2.582	8.62
Nevada	2.786	1.347 - 5.765	17.70
New Hampshire	1.391	0.655 - 2.953	9.34
New Jersey	1.077	0.546 - 2.123	7.34
New Mexico	0.533	0.234 - 1.213	4.06
New York	0.699	0.356 - 1.372	4.80
North Carolina	0.553	0.278 - 1.100	4.27
North Dakota	0.387	0.147 - 1.020	3.00
Ohio	0.960	0.489 - 1.884	6.99
Oklahoma	0.564	0.273 - 1.163	4.14
Oregon	1.104	0.535 - 2.277	7.78
Pennsylvania	1.205	0.617 - 2.354	8.11
Rhode Island	0.277	0.102 - 0.755	2.10
South Carolina	1.715	0.865 - 3.402	11.93
South Dakota	0.573	0.244 - 1.345	3.99
Tennessee	1.270	0.644 - 2.505	8.85
Texas	1.452	0.745 - 2.829	9.84
Utah	2.608	1.273 - 5.341	15.82
Vermont	0.778	0.299 - 2.021	6.29
Virginia	0.631	0.315 - 1.262	4.86
Washington	0.804	0.397 - 1.628	5.81
West Virginia	5.247	2.650 - 10.390	27.63
Wisconsin	0.514	0.255 - 1.035	3.86
Wyoming	1.000	reference state	7.52

[1] Adjusted for patient age, sex, race, Charlson score, subtrochanteric fracture and Medicaid-administered assistance

[2] Rate per 100 Medicare intertrochanteric fractures treated with internal fixation; age 65 or older

Appendix C: 2002 Adjusted odds ratios and rates of intramedullary nail use for intertrochanteric fractures

State	**Adjusted odds ratio**[1] compared to Wyoming	**95% confidence interval for odds ratio**	**Adjusted IMN rate**[1,2]
Alabama	0.902	0.486 - 1.677	9.63
Alaska	0.226	0.028 - 1.806	2.39
Arizona	3.465	1.884 - 6.372	27.79
Arkansas	1.718	0.925 - 3.189	15.99
California	1.987	1.093 - 3.613	18.78
Colorado	1.708	0.912 - 3.197	16.45
Connecticut	1.214	0.646 - 2.283	12.45
Delaware	0.922	0.418 - 2.035	9.41
District of Columbia	1.081	0.430 - 2.718	10.71
Florida	3.742	2.063 - 6.787	28.68
Georgia	1.338	0.728 - 2.457	13.53
Hawaii	1.238	0.567 - 2.701	14.39
Idaho	1.853	0.948 - 3.623	18.21
Illinois	2.441	1.342 - 4.441	21.18
Indiana	2.321	1.270 - 4.242	21.08
Iowa	0.843	0.451 - 1.578	8.87
Kansas	1.660	0.892 - 3.089	17.19
Kentucky	0.987	0.532 - 1.834	10.54
Louisiana	1.734	0.936 - 3.210	17.30
Maine	0.281	0.128 - 0.618	3.41
Maryland	0.964	0.518 - 1.797	9.85
Massachusetts	0.613	0.329 - 1.142	6.60
Michigan	2.587	1.420 - 4.710	22.78
Minnesota	1.032	0.546 - 1.950	11.43
Mississippi	3.647	1.957 - 6.796	28.26
Missouri	1.612	0.880 - 2.956	15.12
Montana	3.705	1.925 - 7.128	29.69
Nebraska	1.790	0.951 - 3.367	16.61
Nevada	2.910	1.522 - 5.563	26.28
New Hampshire	1.584	0.815 - 3.077	15.93
New Jersey	1.838	1.006 - 3.358	17.09
New Mexico	0.935	0.479 - 1.827	10.29
New York	1.520	0.835 - 2.765	14.17
North Carolina	1.003	0.546 - 1.840	10.36
North Dakota	0.799	0.377 - 1.691	9.29
Ohio	1.186	0.649 - 2.166	12.24
Oklahoma	2.598	1.409 - 4.787	22.71
Oregon	1.376	0.729 - 2.596	13.91
Pennsylvania	1.510	0.830 - 2.749	14.48
Rhode Island	0.677	0.290 - 1.577	8.05
South Carolina	3.158	1.720 - 5.801	26.05
South Dakota	1.017	0.512 - 2.018	10.89
Tennessee	2.093	1.144 - 3.828	19.30
Texas	2.005	1.104 - 3.642	18.71
Utah	3.105	1.636 - 5.891	25.34
Vermont	1.496	0.712 - 3.143	15.00
Virginia	1.403	0.762 - 2.582	14.30
Washington	0.934	0.501 - 1.741	10.31
West Virginia	6.317	3.416 - 11.683	40.13
Wisconsin	0.762	0.411 - 1.414	8.26
Wyoming	1.000	reference state	10.92

[1] Adjusted for patient age, sex, race, Charlson score, subtrochanteric fracture and Medicaid-administered assistance
[2] Rate per 100 Medicare intertrochanteric fractures treated with internal fixation; age 65 or older

Appendix D: Patient factors associated with IMN use: results from the surgeon random intercepts model, Chapter 3, Manuscript 2

Covariate	Coefficient	SE	Odds ratio	95% CI
Age				
65-74**§**	-	-	1.00	-
75-84	-0.079	0.035	0.92	0.86 - 0.99
85 years or older	-0.113	0.035	**0.89**	0.84 - 0.96
Sex				
Male	0.080	0.026	**1.08**	1.03 - 1.14
Female**§**	-	-	1.00	-
Race				
White**§**	-	-	1.00	-
Black	0.088	0.063	1.09	0.97 - 1.24
Other	0.042	0.076	1.04	0.90 - 1.21
Location of hip fracture				
Subtrochanteric	2.863	0.031	**17.51***	16.47 - 18.61
Other pertrochanteric**§**	-	-	1.00	-
Residence-state assistance status				
Non-nursing home, no state assistance**§**	-	-	1.00	-
Nursing home, no state assistance	-0.133	0.036	**0.88**	0.82 - 0.94
Non-nursing home, has state assistance	-0.070	0.036	0.93	1.00 - 1.15
Nursing home, has state assistance	-0.072	0.044	0.93	0.85 - 1.01

Medicare intertrochanteric fracture cases treated with IMN or plate/screws 3/1/00-12/31/02 only
bold = p<0.05, **bold*** = p<0.0001
§ =reference level

Appendix E: Relative improvement of model fit by the inclusion of parameter groups and random effects, Chapter 3, Manuscript 2

Model	**Akaike's information criterion (AIC)**	**Bayesian information criterion (BIC)**
Intercept only	142,511	142,521
random hospital intercepts	113,920	113,933
random surgeon intercepts	94,029	94,044
Patient factors, year	132,654	132,776
random hospital intercepts	84,460	84,566
random surgeon intercepts	81,033	132,776
Patient & surgeon factors, year	130,118	130,403
random hospital intercepts	100,313	100,492
random surgeon intercepts	80,560	80.781
Patient, surgeon & hospital factors, year	129,700	130,056
random hospital intercepts	100,228	100,449
random surgeon intercepts	80,541	80,815