Mini-abstract

Among trauma patients, alternative-payment models have met with mixed success given concerns about the heterogeneous nature of trauma patients and resulting outcome variation. This study evaluates a novel approach implemented for hip fractures in England that led to significant improvements in hip fracture outcomes and which could result in >38,000 annual US lives saved.

Abstract

Objective: The objective of this study was to evaluate England's Best Practice Tariff (BPT) and consider potential implications for Medicare patients should the US adopt a similar plan.

Summary Background Data: Since the beginning of the Affordable Care Act, Medicare has renewed efforts to improve the outcomes of older adults through introduction of an expanding set of alternative-payment models. Among trauma patients, recommended arrangements met with mixed success given concerns about the heterogeneous nature of trauma patients and resulting outcome variation. A novel approach taken for hip fractures in England could offer a viable alternative.

Methods: Linear regression, interrupted time-series, difference-in-difference, and counterfactual models of 2000-2016 Medicare (US), HES-APC (England) death certificate-linked claims (≥65y) were used to: track US hip fracture trends, look at changes in English hip fracture trends before-and-after BPT implementation, compare changes in US-versus-English mortality, and estimate total/theoretical lives saved.

Results: 806,036 English and 3,221,109 US hospitalizations were included. Following BPT implementation, England's 30-day mortality decreased by 2.6 percentage-points (95%CI: 1.7-3.5) from a baseline of 9.9% (relative reduction 26.3%). 90- and 365-day mortality decreased by 5.6 and 5.4 percentage-points. 30/90/365-day readmissions also declined with a concurrent shortening of hospital length-of-stay. From 2000-2016, US outcomes were stagnant ($p>0.05$), resulting in an inversion of the countries' mortality and >38,000 potential annual US lives saved.

Conclusions: Process measure pay-for-performance led to significant improvements in English hip fracture outcomes. As efforts to improve US older adult health continue to increase, there are important lessons to be learned from a successful initiative like the BPT.

Key words: older adult; Medicare; hip fracture; trauma; pay-for-performance; process measure; mortality

Learning from England's Best Practice Tariff: Process Measure Pay-for-Performance Can Improve Hip Fracture Outcomes

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Introduction

Traumatic injuries are a leading cause of death and loss-of-independence for the >51 million people aged ≥65y living in the United States (US).[1] In 2017 alone, 4.8 million non-fatal traumatic injuries were reported among older adults, of which 1.2 million required hospitalization.[2] An additional 66,000 older adults died during hospitalization as a result of their injuries, costing hospitals and payers >$1.5 billion (2019 USD) in direct medical costs.[2] Hip fractures (accounting for >200,000 hospitalizations, 5,000 in-hospital deaths) are among the most common and debilitating forms of injuries among older adults, often resulting in long-term functional impairment, nursing-home admission, and shortened life-expectancy. 1-in-5 hip fracture patients die within 1 year of injury.[3] 1-in-3 who lived independently before a hip fracture remain in a nursing-home for at least 1 year after injury,[3] and 1-in-10 will require readmission within 30 days[4] at an additional cost >$14,000 per patient.[5]

Since the beginning of the Patient Protection and Affordable Care Act in 2010 and Medicare Access and CHIP Reauthorization Act in 2015, Medicare has renewed efforts to improve the outcomes of older adults through the introduction of an expanding set of alternative-payment models. Among hip fracture patients, two potential[6] (outcome-based pay-for-performance), attempted[7] (bundled payments) arrangements have met with mixed success given concerns within the orthopaedic and trauma communities about the heterogeneous nature of trauma patients and resulting outcome variation. The 'unpredictability' of trauma outcomes combined with their dependence on fixed patient factors makes penalizing trauma mortality unpopular[6] and incorporating hip fractures in bundles along with elective procedures (hip arthroplasty for arthritis)[7] an expressed cause for concern.[8–11]

Other potential options, such as focusing on process-based pay-for-performance and/or hip fracture-specific process-of-care bundled models, merit careful consideration. For non-trauma patients (heart failure, acute myocardial infarction, pneumonia), Medicare's early efforts to evaluate process measures suggested significant improvements in mortality.[12–15] However, when process measures were incorporated in the Hospital Value-Based Purchasing Program (HVBP)[6] alongside patient experience and outcome measures, no improvements compared to non-program hospitals were found.[16] Existing adoption of recommended process measures,[17] missed 'clinical' process needs,[18] and underlying issues with the HVBP itself[16] are thought to have contributed to the lack of meaningful variation in mortality explained.[19]

A novel approach taken by the National Health Service (NHS) in England could offer a viable alternative. Recognizing the importance of hip fracture patients and challenge of incentivizing improvements in hip fracture outcomes, the NHS established a national clinical audit in 2007 with the expressed goal of reducing hip fracture mortality by promoting care-coordination and targeting a related set of clinician-determined process measures (Figure 1). The program created a publicly-available clinical registry (National Hip Fracture Database [NHFD]) and, in 2010, introduced a process measure-based pay-for-performance supplement to hip fracture claims known as the Best Practice Tariff (BPT). National studies in England suggest significant improvements in 30-day mortality for adults aged ≥60y following introduction of the NHFD[20] and, more pronounced, full implementation of the BPT.[21] The objective of this study was to expand on that work, confirming effectiveness of the BPT on improving outcomes for older adults aged ≥65y (US Medicare eligibility starts at 65y), analyzing concurrent hip fracture trends in the US, and considering potential implications for Medicare patients should the US adopt a similar plan.

Methods

Data source and study population

Records of index hip fracture admissions for Medicare patients aged ≥65y were abstracted using 2000-2016 Medicare Provider Analysis and Review (MEDPAR) files. MEDPAR contains discharge information for 100% of fee-for-service hospitalizations among

Medicare beneficiaries, representing >70% of all Medicare beneficiaries nationwide. Inpatient data from 12 months prior were assessed for comorbidities. Death certificate-linked mortality was tracked through December 2018. In order to be considered an index admission, patients needed to present with a primary hip fracture diagnosis and not have been admitted for a similar diagnosis in the proceeding 30 days. Patients within non-continuous Medicare fee-for-service enrolment in the 12 months prior to and 30 days following index admission were excluded as were those missing information for explanatory/confounding variables of interest (date of birth required to calculate patient age, date of index hospital admission, gender, and presence of primary/secondary diagnosis codes used to calculate Elixhauser comorbidities: <0.1%).

Similar criteria were used to identify hip fractures in England; 2000-2016 inpatient claims from England's Hospital Episode Statistics Admitted Patient Care dataset (HES-APC)[22] were queried and linked to civil death registrations available through March 2018.[21] In England, HES-APC collects information on admissions to NHS hospitals and NHS-funded admissions to private hospitals, a combined group representing >98% of hospital admissions. As with Medicare claims, patients lacking 12-month prior and 30-day follow-up records were excluded as were those missing information for explanatory/confounding variables of interest (<0.5%). Given minimal missing data and presumed randomness of missing information in both US and English hip fracture claims, data from each country were analyzed using a complete-case analysis approach.

Explanatory and outcome variables

The study's primary outcome was 30-day mortality measured from a patient's date of index admission. No distinctions were made for different causes of death; all deaths were death certificate-linked. Secondary outcomes looked at changes in 90-day mortality, 365-day mortality, primary hip fracture incidence, median index hospital charges and Medicare reimbursement (adjusted for inflation to 2019 USD), 30-day readmission (measured from a surviving patient's data of discharge), 90-day readmission, 365-day readmission, index hospital length-of-stay, and receipt of a timely operation (Figure 1).

Explanatory variables included changes over time and country-of-origin (US-versus-England). In the first analysis, trends for US hip fracture patients were tracked by year from 2000-2016. In the second, outcomes for English hip fracture patients were assessed before introduction of the NHFD (January 2000-December 2006) and after full implementation of the BPT (April 2010-December 2016). The third incorporated US hip fracture trends, looking at changes in US-versus-English mortality, while the fourth asked what could happen to hip fracture mortality were the US to have implemented an initiative similar to the BPT. All models were risk-adjusted for age, gender, and Elixhauser comorbidities.

Statistical analysis

Differences in demographic characteristics between England and the US were compared overall and before-and-after BPT implementation using descriptive statistics. Variables included: age, gender, race (US), Index of Multiple Deprivation (England), and 29 individual Elixhauser comorbidities. Changes in US temporal trends (analysis 1) were assessed using linear regression in order to attain risk-adjusted average annual changes and corresponding 95% confidence intervals (95%CI).

In analysis 2, risk-adjusted interrupted time-series analysis (ITSA) was used to assess changes in English temporal trends before-and-after BPT implementation. ITSA is a quasi-experimental modelling technique designed to mimic the results of randomized, controlled trials in settings such as national health policy implementation where randomization and experimental intervention are not plausible. It functions by fitting linear models to changes over time before-and-after policy implementation and looking for a sudden jump or unanticipated 'interruption' in where the two models coincide. Interruptions occurring at the time of policy implementation are assumed to be a result of the policy.

In analysis 3, temporal trends for mortality in each country were combined using a second quasi-experimental, risk-adjusted difference-in-difference (DID) analysis approach. Like ITSA, DID attempts to disentangle causal and temporal effects by comparing aggregated before-and-after changes in an exposed (England) and unexposed (US) population. The idea behind the approach based on inclusion of an interaction term in a linear regression model ($E[Y]=B_0+B_{US\text{-}versus\text{-}England}+B_{after\text{-}versus\text{-}before}+B_{country*time\text{-}period}+B_{confounders}$) suggests that if 'differences' between countries 'differ' ('difference-in-difference') before-and-after policy implementation, then the change in differences must be attributable to policy implementation. In this case, prior research[20,21] and our own ITSA showed that the BPT was effective. In comparing English and American mortality, we were more interested in determining the extent to which anticipated changes in England outpaced those in the US. Secondary analyses isolated effects of the NHFD (2007) and payment component of the BPT (2010).

Finally, in analysis 4, counterfactual models and calculation of risk-adjusted observed/expected (O/E) mortality ratios were used to determine theoretical reductions in mortality were the US to have implemented an initiative similar to the BPT. We used this information to calculate corresponding average annual 'life savings' observed in England and theoretically attainable in the US.

Data management and cleaning were completed in SAS: Version 9.4; statistical analyses were conducted using Stata Statistical Software: Version 16.0. Graphs were plotted in R. All models accounted for clustering of patients within hospitals and were analyzed using robust standard errors. The Yale Human Investigation Committee and US Centers for Medicare & Medicaid Services approved use of Medicare data. The NHS Independent Group Advising on the Release of Data in the United Kingdom approved use of routinely-collected NHS data.[21]

Results

A total of 3,221,109 US hip fracture hospitalizations and 806,036 English hip fracture hospitalizations satisfied inclusion criteria. Differences in demographic characteristics are presented in Table 1. Overall, the populations were largely comparable with little to no meaningful clinical differences between them nor changes over time. Statistical differences are omitted given the large sample size.

Analysis 1: Changes in US hip fracture trends

Annual changes in US hip fracture trends are presented in Figure 2 (monthly changes in 30-day mortality in grey in Figure 1). Between 2000-2016, the annual incidence of US hip fractures declined, mostly notably among adults aged 75-84y beginning in approximately 2006 and plateauing around 2012. Changes among adults aged ≥85y were steadier with an average annual decline of 910 cases per year (95%CI: 973-848), while those among adults aged 65-74y did not meaningfully change (Figure 2A). Median total hospital charges, in contrast, increased by a risk-adjusted average of $2,880 per year (95%CI: $2,840-2,920). Medicare reimbursement increased by an average of $430 per year ($400-480)—resulting in an uncompensated difference of $51,180 per patient by 2016 (Figure 2B).

Differences in mortality were minimal. Overall, no significant changes were found at endpoints measured at 30, 90, or 365 days. When stratified by age (Figure 2C), 30-day mortality among adults aged 65-74y decreased by an average of 0.1 percentage-points per year (95%CI: 0.1-0.1). Results for readmission and length-of-stay were not significant.

Analysis 2: Changes in English hip fracture trends

Annual changes in English hip fracture trends are summarized before-and-after BPT implementation in Table 2 (monthly changes in 30-day mortality in black/white in Figure 1). Prior to BPT implementation (2000-2006), 90- and 365-day mortality were increasing (*e.g.* 365-day: +0.3 percentage-points/year) as were 30/90/365-day readmissions (365-day: +0.8

percentage-points/year). Upon introduction of the NHFD in 2007 and payment supplements in 2010, larger improvements were seen. 30-day mortality decreased by 2.6 percentage-points (95%CI: 1.7-3.5) from a baseline of 9.9% (relative reduction 26.3%). 90- and 365-day mortality decreased by 5.6 and 5.4 percentage-points, respectively (relative reductions 28.3% and 16.6%). Readmissions also declined, dropping by 1.4 percentage-points (95%CI: 0.5-2.3) within 30 days. Length-of-stay decreased, while the percentage of patients receiving a timely operation increased (15.1 percentage-points, 95%CI: 13.3-16.8), reflecting a concurrent improvement in process measure utilization (Figure 1).

After full implementation of the BPT (2010-2016), annual increases in longer-term mortality and readmission ceased, with values remaining relatively constant at post-implementation levels. Marginally-significant additional reductions in 30-day mortality, average 0.2 percentage-points per year, were found (95%CI: 0.1-0.4; Table 2). Length-of-stay continued to decrease, while the percent of patients receiving a timely operation increased by an average of 1.0 percentage-points per year (95%CI: 0.7-1.2).

Analysis 3: Aggregated changes in mortality US-versus-England

DID analysis comparing temporal changes in England and the US found significantly larger reductions in English hip fracture mortality compared to the US (Table 3). Prior to BPT implementation in England, England's 30-day mortality for hip fracture (9.9%) exceeded that of the US (8.4%) by an average of 1.5 percentage-points—a difference which can clearly be seen in Figure 1. Following implementation, England's 30-day mortality (7.2%) decreased to an average of 0.7 percentage-points lower than that in the US (7.9%)—a difference which can again clearly be seen in Figure 1. The drop resulted in an overall aggregated difference-in-difference of 2.2 percentage-points. Similar patterns were observed at 90 and 365 days. Stratified changes separating the influence of the clinical registry and payment supplement suggest significant mortality decreases attributable to each but larger values associated with the introduction of payment incentives (30-day DID of 0.7 versus 1.6 percentage-points).

In England, these changes representing reductions in 'expected mortality' correspond to risk-adjusted O/E mortality ratios of 0.73 (30 days), 0.72 (90 days), and 0.83 (365 days). They mean that full implementation of the BPT resulted in an average of 4,881 fewer 30-day deaths each year in England among adults aged ≥65y (10,373 fewer deaths within 90 days, 19,390 fewer deaths within 365 days).

Analysis 4: Hypothetical implementation in the US

Were a similar initiative to have been implemented in the US in 2010 (Table 3), by 2016, a total of 82,936 fewer deaths within 30 days could be expected to be seen. This hypothetical change corresponds to an average of 11,484 fewer deaths per year (95%CI: 10,900-12,100) and a theoretical reduction in 30-day mortality from 7.9% to 5.7%. Within 90 days, 201,068 fewer deaths could be expected at an average of 28,724 fewer deaths per year (95%CI: 28,300-29,200; theoretical-versus-observed mortality: 13.9% versus 19.3%). Within 365 days, 268,478 fewer deaths could be expected at an average of 38,354 fewer deaths per year (95%CI: 30,100-38,700; theoretical-versus-observed mortality: 18.6% versus 22.5%).

Discussion

The results of this study demonstrate that in contrast to purported efforts to improve hip fracture mortality among older adults in the US,[6,7] a novel approach taken by the NHS in England markedly improved hip fracture mortality. By targeting an evolving set of clinician-determined process measures (Figure 1), the BPT proves that process measure pay-for-performance can improve trauma outcomes and could result in significant improvements in US hip fracture mortality while remaining more applicable to heterogeneous trauma populations and ideally less objectionable to providers.[8–11] The nuances of adapting such a program and advocating for implementation in surgical quality improvement and Medicare benchmarking are beyond the scope of this work. However, the results show that as efforts to improve US older adult health continue to increase, there are important lessons to be learned from a successful initiative like the BPT.

Analysis of US hip fracture trends revealed that despite decreasing incidence of hip fracture hospitalizations, mortality remained unchanged and charges increased. The result when measuring value as 'changes in quality [commonly interpreted to mean outcomes] divided by cost' is a steadily worsening value-of-care for hip fracture patients and a growing divide between what hospitals charge and Medicare reimbursement pays. Prior studies have pointed toward a similar decline in the rate of hip fracture hospitalization.[23–26] Their discussion of increasing bisphosphonate use and reduction in estrogen therapy,[23,24,27] emergence of public health fall education campaigns,[28–30] and contested utility of ongoing changes in operative trends,[31–34] likely explains much of the decreasing incidence observed (particularly the drop between 2006-2012 among adults aged 75-84y) but does nothing to obviate the increasing costs or stagnant mortality. For that, something more needs to change.

It is here that the idea of process-measure utilization as reflected in the BPT is intriguing. Rather than targeting 'administrative' aspects of process measures[18] or recommending already widely-accepted processes[17] and adding on permanent payment incentives/penalties,[16] the NHS in England adopted largely unmet standards for clinical improvement that are able to be updated over time (Figure 1) based on shared consensus between orthopaedic surgeons and geriatricians. The resulting program included metrics thought to lead to mortality improvement and focused on enhancing care-coordination for hip fractures patients as they move from the hospital to rehabilitation and home. Such an approach is in many ways the same idea behind Medicare's current bundled payment model in the US, but with the critical distinction that it encourages, instead of limits, transitions to post-discharge care (a potentially troubling result identified by early analyses of existing US bundles for lower-limb arthroplasty).[35,36] It is also the rationale behind the US American College of Surgeons' new quality improvement initiative designed to create and verify geriatric surgical centers.[37] Both approaches if developed in line with lessons learned from the BPT have the potential to meaningfully change outcomes of one of the most common and debilitating forms of injury/illness encountered among older adults.

While our study demonstrates the potential benefits that a policy similar to the BPT could have on hip fracture care, there are also potential challenges to implementation, many of which derive from differences between the NHS and American health system. Foremost, it is unclear whether the same level of national consensus could be achieved among US orthopaedic surgeons and geriatricians regarding which process measures should be used to evaluate performance. Short of developing a new set of process measures for the US, performance measures employed by the NHS could be substituted or recommendations adopted from the American Academy of Orthopaedic Surgeons clinical practice guidelines.[38] However, it is unknown whether such an approach would instill a similar degree of ownership among clinicians as was achieved in the NHS where national provider consensus was sought.

Hip fractures in the US are treated at both tertiary academic medical centers and smaller community hospitals. In implementing a BPT-like initiative, there could be concern that implementation would materially disadvantage institutions with already restricted resources, creating an impaired capacity to effectuate meaningful change. The resultant financial impact on community hospitals could lead to reduced access to hip fracture care among rural populations and minority patients. Similar phenomena have been documented in other well-intended healthcare reform efforts enacted by Medicare.[39] Unlike the NHS, many US hospitals do not have direct operational control over all of the mechanisms necessary to respond to a BPT-like initiative. Surgeons, geriatricians, and anesthesiologists might not be hospital employees and/or there might not be ready integration with compensated post-discharge care (inpatient rehabilitation facilities, outpatient physical therapy visits) needed to ensure optimal recovery of patients.[40] Financial incentives directed at US hospitals alone could prove insufficient to motivate change among these other partners in the delivery of care. Boarder initiatives that encompass processes across the spectrum of hip fracture care and which ensure adequate access to post-discharge care will likely be needed in order to achieve similar improvements in outcomes over time.

The study has some limitations, most of which reflect its reliance on administrative claims. In using US Medicare and English HES-APC data, we were able to attain national, longitudinal records of the majority of older adults in each country. No other databases enable such assessment needed to evaluate national health policy change. The robustness of Medicare/HES-APC data, including its links to death-certificate registrations that reflect mortality both in and outside of hospital systems and availability of 12-month look-back for comorbidities; use of a population like hip fracture which is likely to be readily identified and reported in billing claims; and similar way in which Medicare and HES-APC report data help to allay the majority of concerns. Nevertheless, in comparing data from two counties, there is always the possibility that hospital records do not reflect patient experiences in the same way or that the countries themselves, despite similar demographics, cannot be directly compared.

Process measure pay-for-performance in England resulted in significant improvements in outcomes for hip fracture patients at rates outpacing stagnant temporal changes in the US. Counterfactual modelling suggests that were a similar initiative to be implemented among US Medicare patients, >38,000 lives could be saved every year. As efforts to improve US older adult health continue to increase, there are important lessons to be learned from a successful trauma initiative like the BPT.

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Figure legends:

Figure 1. Monthly 30-day hip fracture mortality among adults aged ≥65y in England (black/white) and the United States (grey), 2000-2016

Figure 2. Changes in United States hip fracture **(A)** incidence (by age: 65-74, 75-84, ≥85y), **(B)** expense (charges, Medicaid payment in 2019 USD), and **(C)** 30-day mortality (by age: 65-74, 75-84, ≥85y), 2000-2016. Points show observed annual data with linear plots; average annual changes were taken from risk-adjusted linear regression models (omitted for non-linear incidence among adults aged 75-84y). The omitted incidence instead shows an unadjusted locally-weighted least squares regression

Table 1

Table 1. Differences in demographic characteristics for adults aged ≥65y before-and-after BPT

	Overall: January 2000-December 2016				**Pre-intervention:** January 2000-December 2006		**Post-intervention:** April 2010-December 2016	
	United States		**England**		**United States**	**England**	**United States**	**England**
Number of hip fractures (N)	3,221,109	78.4%	886,038	21.6%	1,450,579	389,857	1,207,516	354,415
Age on index admission (years)								
65-74	511,682	15.9%	124,931	14.1%	16.4%	13.3%	15.4%	14.9%
75-84	1,317,868	40.9%	339,707	38.3%	39.3%	39.4%	42.5%	37.3%
≥ 85	1,391,559	43.2%	421,400	47.6%	44.1%	47.3%	42.3%	47.8%
Gender								
Male	830,241	25.8%	226,560	25.6%	24.1%	24.2%	27.1%	28.2%
Female	2,390,868	74.2%	659,478	74.4%	75.9%	75.8%	72.9%	71.9%
Race (US only)								
White	2,993,216	92.9%	--	--	93.1%	--	92.5%	--
Black	115,557	3.6%	--	--	3.7%	--	3.6%	--
Other	112,336	3.5%	--	--	3.2%	--	3.9%	--
Multiple deprivation index (England only)			-					
Least deprived 10%	--	--	80,009	9.0%	--	8.4%	--	9.9%
Less deprived 10-20%	--	--	88,870	10.0%	--	9.7%	--	10.5%
Less deprived 20-30%	--	--	91,794	10.4%	--	10.1%	--	10.8%
Less deprived 30-40%	--	--	94,009	10.6%	--	10.4%	--	11.0%
Less deprived 40-50%	--	--	95,515	10.8%	--	10.7%	--	11.1%
More deprived 40-50%	--	--	93,034	10.5%	--	9.9%	--	8.6%
More deprived 30-40%	--	--	88,692	10.0%	--	10.1%	--	9.3%
More deprived 20-30%	--	--	87,186	9.8%	--	10.1%	--	9.8%
More deprived 10-20%	--	--	83,110	9.4%	--	10.6%	--	10.5%
Most deprived 10%	--	--	83,908	9.5%	--	10.2%	--	8.5%
Elixhauser comorbidities (one-year hospital look back)								
Congestive heart failure	549,816	17.1%	138,456	15.6%	17.2%	15.3%	16.9%	16.0%
Valvular disease	398,719	12.4%	94,758	10.7%	12.4%	10.2%	12.3%	11.2%
Pulmonary circulatory disorder	194,111	6.0%	113,660	12.8%	6.3%	12.4%	5.8%	13.3%
Peripheral vascular disorder	282,639	8.8%	54,052	6.1%	9.0%	6.4%	8.5%	5.8%
Hypertension	2,498,475	77.6%	685,007	77.3%	77.8%	76.9%	77.4%	77.7%
Paralysis	64,608	2.0%	8,383	0.9%	1.9%	0.9%	2.1%	1.0%
Neurodegenerative disorder	326,159	10.1%	56,071	6.3%	10.3%	6.3%	10.0%	6.3%
Chronic pulmonary disease	758,768	23.6%	208,150	23.5%	23.8%	23.1%	23.3%	23.9%
Diabetes, uncomplicated	636,060	19.7%	132,692	15.0%	19.9%	14.8%	19.6%	15.2%
Diabetes, complicated	103,513	3.2%	23,422	2.6%	3.4%	2.9%	3.1%	2.3%
Hypothyroidism	784,291	24.3%	234,617	26.5%	24.5%	26.2%	24.2%	26.8%
Renal failure	613,404	19.0%	151,424	17.1%	19.2%	16.7%	18.9%	17.5%
Liver disease	44,944	1.4%	7,780	0.9%	1.5%	0.6%	1.3%	1.2%
Peptic ulcer disease excluding bleeding	13,399	0.4%	48,463	5.5%	0.5%	5.1%	0.3%	5.8%
AIDS/HIV	18,187	0.6%	4,841	0.5%	0.7%	0.5%	0.4%	0.6%
Lymphoma	32,906	1.0%	19,600	2.2%	1.1%	2.4%	1.0%	2.0%
Metastatic cancer	44,608	1.4%	5,183	0.6%	1.3%	0.1%	1.5%	1.0%
Solid tumor without metastasis	68,834	2.1%	6,657	0.8%	2.2%	0.7%	2.1%	0.8%
Rheumatoid arthritis/collagen vascular disease	134,201	4.2%	26,011	2.9%	4.0%	2.6%	4.4%	3.3%
Coagulopathy	256,074	7.9%	80,736	9.1%	8.0%	9.1%	7.9%	9.1%
Obesity	143,647	4.5%	33,812	3.8%	4.6%	3.7%	4.4%	3.9%
Weight loss	237,774	7.4%	62,661	7.1%	7.4%	7.3%	7.3%	6.9%
Fluid and electrolyte disorder	1,104,838	34.3%	290,803	32.8%	34.5%	32.8%	34.1%	32.9%
Blood loss anemia	89,454	2.8%	45,787	5.2%	2.9%	4.9%	2.7%	5.4%
Deficiency anemias	884,896	27.5%	265,914	30.0%	27.6%	29.6%	27.4%	30.4%
Alcohol abuse	81,977	2.5%	18,481	2.1%	2.4%	1.6%	2.7%	2.5%
Drug abuse	23,526	0.7%	46,062	5.2%	0.8%	5.3%	0.7%	5.1%
Psychosis	117,204	3.6%	7,353	0.8%	3.4%	1.0%	3.8%	0.7%
Depression	550,995	17.1%	155,075	17.5%	17.2%	17.5%	17.1%	17.5%

Table 2

Table 2. Interrupted time-series analysis (ITSA) before-and-after BPT implementation in England among adults aged ≥65y, 2000-2016

	Pre-intervention: January 2000-December 2006			Intervention implementation Change from pre- to post-			Post-intervention: April 2010-December 2016		
Outcome	**Annual trend**	**95%CI**		**'Interruption'**	**95%CI**		**Annual trend**	**95%CI**	
Mortality, %									
30-day	0.0	-0.1	0.2	-2.6	-3.5	-1.7	-0.2	-0.4	0.0
90-day	0.2	0.1	0.4	-5.6	-7.1	-4.2	-0.2	-0.5	0.1
365-day	0.3	0.1	0.4	-5.4	-6.5	-4.2	-0.1	-0.2	0.1
Readmission, %									
30-day	0.4	0.3	0.5	-1.4	-2.3	-0.5	-0.2	-0.4	-0.1
90-day	0.7	0.5	0.8	-1.4	-2.3	-0.4	-0.1	-0.2	0.0
365-day	0.8	0.6	0.9	-1.2	-2.2	-0.2	0.0	-0.1	0.0
Length-of-stay in days									
50th percentile (median)	-0.1	-0.1	0.0	-2.7	-3.5	-2.0	-0.6	-0.8	-0.4
60th percentile	-0.1	-0.2	0.0	-4.0	-4.9	-3.1	-0.6	-0.8	-0.4
70th percentile	-0.1	-0.3	0.0	-5.0	-6.2	-3.9	-0.9	-1.0	-0.5
80th percentile	-0.3	-0.5	-0.1	-6.3	-8.0	-4.7	-1.4	-1.8	-1.1
Timely operation, %	-0.6	-0.9	-0.3	15.1	13.3	16.8	1.0	0.7	1.2

Length-of-stay in England includes inpatient rehabilitation.
Grey shading denotes statistical significance (two-sided p-value<0.05).

Table 3

Table 3. Difference-in-difference (DID) results comparing the United States and England, 2000-2016, and counterfactual models showing the annual number of deaths averted in England and the theoretical number of deaths that could have been averted in the United States, 2010-2016

I. Difference-in-Difference: United States versus England

	Pre-intervention: January 2000-December 2006			Post-intervention: April 2010-December 2016			Intervention implementation Change from pre- to post-		
Outcome	United States	England	'Difference'	United States	England	'Difference'	DID	95%CI	
Mortality, %									
30-day	8.4%	9.9%	-1.5%	7.9%	7.2%	0.7%	-2.2%	-2.2%	-2.2%
90-day	20.8%	19.8%	1.0%	19.3%	15.3%	4.0%	-2.9%	-2.9%	-2.9%
365-day	24.5%	32.5%	-8.0%	22.5%	28.6%	-6.1%	-1.9%	-1.9%	-1.9%

	During implmentation January 2007-March 2010			I. Pre-implmentation vs Registry Change from pre- to implmentation			II. Registry vs Payment Supplement Change from implementation to post-		
Outcome	United States	England	'Difference'	DID	95%CI		DID	95%CI	
Mortality, %									
30-day	8.1%	9.0%	-0.9%	-0.7%	-0.7%	-6.6%	-1.6%	-1.6%	-1.6%
90-day	20.3%	18.1%	2.2%	-1.2%	-1.2%	-1.2%	-1.7%	-1.7%	-1.7%
365-day	23.9%	30.8%	-6.9%	-1.0%	-1.0%	-1.0%	-0.8%	-0.9%	-0.8%

*DID = 'Difference-in-Difference'

Grey shading denotes statistical significance (two-sided p-value<0.05)

Models were risk-adjusted for: patient age on index admission, gender, and individual Elixhauser comorbidities

II. Counterfactual model: Hypothetical implmentation in the United States

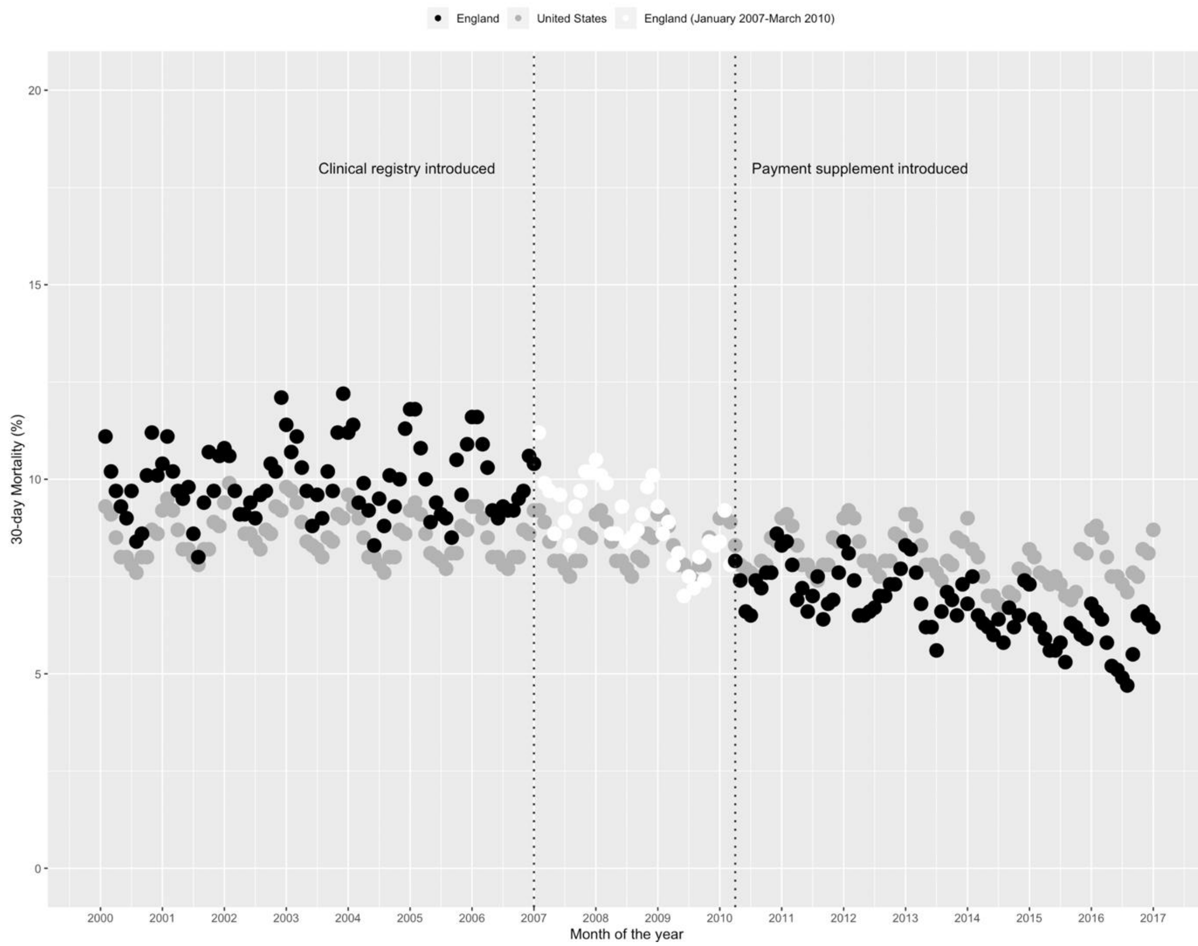
	England			O/E Ratio	Annual deaths averted
Outcome	O: 2000-2006	O: 2010-2016	E: 2010-2016	2010-2016	2010-2016
Mortality, %					
30-day	9.9%	7.2%	9.9%	0.73	4,881
90-day	19.8%	15.3%	21.2%	0.72	10,373
365-day	32.5%	28.6%	34.6%	0.83	19,390

	United States			O/T Ratio	Annual deaths averted
Outcome	O: 2000-2006	O: 2010-2016	T: 2010-2016	2010-2016	2010-2016
Mortality, %					
30-day	8.4%	7.9%	5.7%	0.73	11,848
90-day	20.8%	19.3%	13.9%	0.72	28,724
365-day	24.5%	22.5%	18.6%	0.83	38,354

*O = Observed, E = Expected, T = Theoretical

Expected deaths obtained from models that accounted for differencs in patient age on index admission, gender, and individual Elixhauser comorbidities

Figure 1



Eligibility for payment of the English Best Practice Tariff (BPT)

- Aged ≥60y at time of admission
- Valid National Health Service number
- Receive a timely operation (time to surgery <36 hours after arrival in the ED)
- **<u>All</u>** of the following:

Hip fractures after 2010	Hip fractures after 2012	Hip fractures after 2017
Admitted under named orthopaedic surgeon Admitted under named geriatrician Admitted using a joint assessment protocol Timely geriatrician assessment (<72 hours) Rehabilitation assessment Specialist falls assessment Bone therapy assessment	Admitted under named orthopaedic surgeon Admitted under named geriatrician Admitted using a joint assessment protocol Timely geriatrician assessment (<72 hours) Rehabilitation assessment Specialist falls assessment Bone therapy assessment Documentation of pre-op AMTS Documentation of post-op AMTS	Timely geriatrician assessment (<72 hours) Specialist falls assessment Bone therapy assessment Documentation of pre-op AMTS* Delirium assessment Physiotherapist assessment Nutrition assessment

*AMTS = Abbreviated Mental Test Score

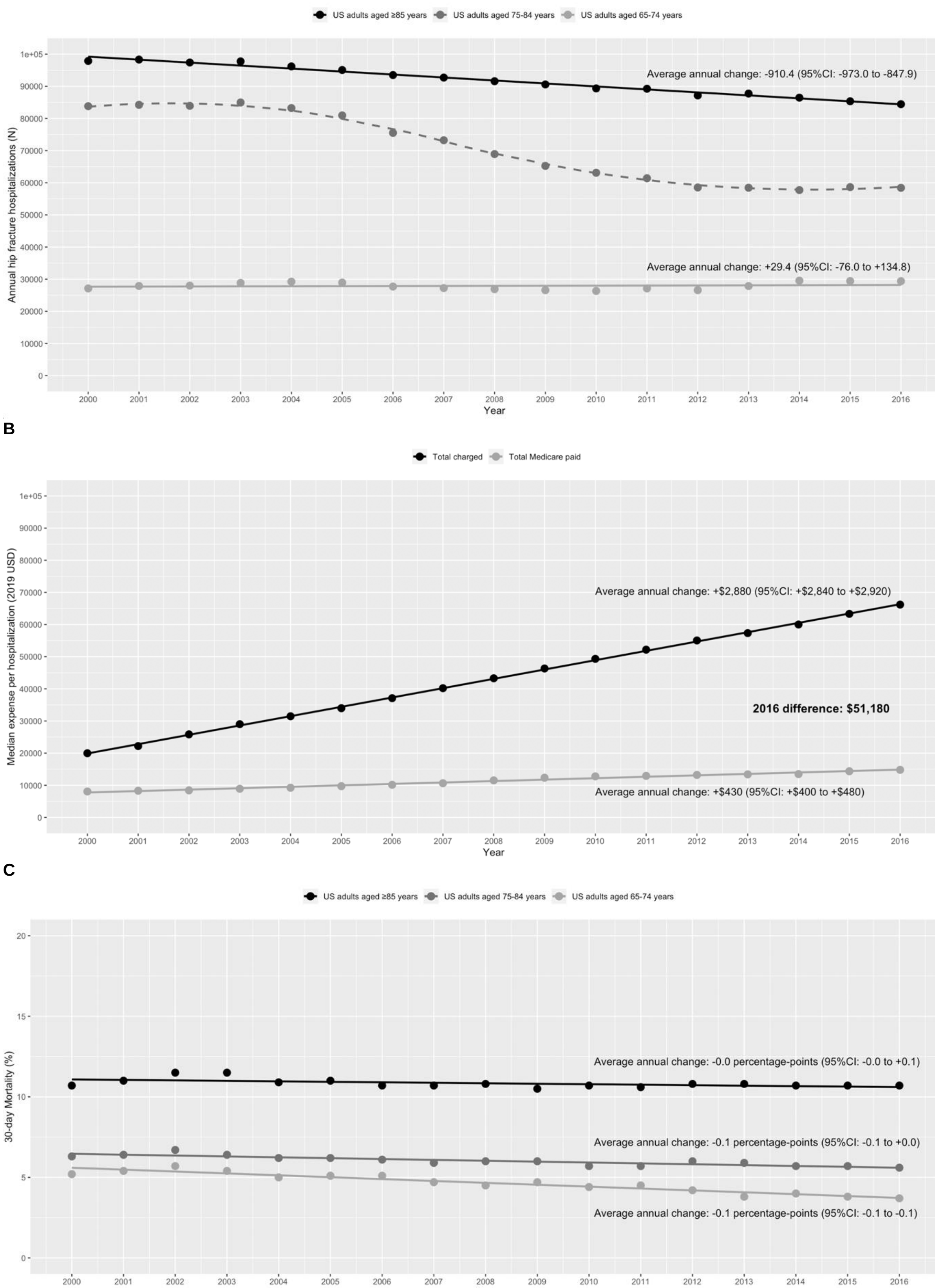
Figure 1.

Figure 2

A

B

C



US adults aged ≥85 years
US adults aged 75-84 years
US adults aged 65-74 years
Annual hip fracture hospitalizations (N)
Year
Average annual change: -910.4 (95%CI: -973.0 to -847.9)
Average annual change: +29.4 (95%CI: -76.0 to +134.8)
Total charged
Total Medicare paid
Median expense per hospitalization (2019 USD)
Average annual change: +$2,880 (95%CI: +$2,840 to +$2,920)
2016 difference: $51,180
Average annual change: +$430 (95%CI: +$400 to +$480)
30-day Mortality (%)
Average annual change: -0.0 percentage-points (95%CI: -0.0 to +0.1)
Average annual change: -0.1 percentage-points (95%CI: -0.1 to +0.0)
Average annual change: -0.1 percentage-points (95%CI: -0.1 to -0.1)

Figure 2.

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