Appendix: Full Analysis Section

Bivariate associations between volume and each binary outcome were evaluated in logistic regression models that employed generalized estimating equations to account for the clustering of patients within hospitals[24]. Next, for each outcome, we constructed two sets of multivariate models, one examining the association between outcomes and hospital-volume strata and the other examining the association between outcomes and surgeon-volume strata. The hospital-volume models included indicator variables corresponding to hospital-volume strata, with the lower-volume stratum serving as the reference category. In these models, surgeon volume was represented by an ordinal variable summarizing surgeon-volume strata. Similarly, models of the effects of surgeon volume used dummy variables to represent surgeon volume, an ordinal variable to represent hospital volume, and important covariates, as discussed below. In both sets of models, the ordinal volume variable was used to examine the linear trend.

In each model, we adjusted for prognostically important covariates. These included age (<75 vs. ≥75 years old), gender, Charlson comorbidity score (0, 1, 2, ≥3), specific arthritis diagnosis (rheumatoid arthritis, avascular necrosis, osteoarthritis), and Medicaid eligibility indicator. Hospital location, ownership, teaching status, and nurse staffing ratios as well as the number of years since the surgeon graduated from medical school were not associated with outcomes and/or did not influence the association between volume and outcome. Therefore these variables were not included in the final models.

The strength of association between volume and outcome was expressed with an adjusted odds ratio, calculated as the odds of having the outcome within a particular volume category divided by the odds in the lowest-volume category. Given that the outcomes are infrequent, odds ratios closely approximate risk ratios.

We examined more explicitly the simultaneous effects of both hospital and surgeon volume on dislocation following primary total hip replacement. We chose to analyze dislocation in detail because surgeon and hospital volume independently influenced dislocation rates of primary total hip replacement. We carried these analyses out in hospitals with at least twenty-five primary total hip replacements per year, as high-volume surgeons did not operate in hospitals with smaller volumes. We ran additional logistic regression models of the surgeon effect within each hospital stratum (26-50, 51-100, >100). These models were adjusted for the same set of covariates as described above. Surgeon-volume effect was evaluated by using indicator variables. We also ran models with surgeon volume represented by an ordinal variable to test for trend.

All analyses were performed with SAS[23]; generalized estimating equations (Proc Genmod in SAS) were employed to adjust for clustering within hospitals.

Algorithm for Primary Total Hip Replacement

July 14th, 1999

Claims from Skilled Nursing Facilities will not be used to define the cohort, but may be used to exclude. NO outpatient data will be used.

Selecting codes

Select all cases with an INPATIENT ICD-9 procedure code of

81.51 Total hip replacement,

and/or with a surgical claim with a CPT code of

27130 Total hip replacement.

A single surgical claim is accepted as a case only if the patient was in fact in the hospital on that date.

NO additional confirming evidence

Exclusions

Hip or other femur fractures

All patients with a code for femur fracture during the index admission, in a transfer IN, or (CPTs) within 2 days of the index surgical claim, are excluded. The excluding codes are:

ICD-9 diagnoses 820-821.11
ICD-9 procedures 79.05, 79.15, 79.25, 79.35
CPT codes 27230-27248, 27500-27507.

Conversion of previous hip surgery to THR

All patients with CPT code 27132 during the index admission, in a transfer IN, or within 2 days of the index surgical claim, are excluded.

Infection of pelvic region and thigh

All patients with a code for Arthropathy associated with infections; Osteomyelitis, periostitis and other infections involving bone; or hip arthrotomy for infection with drainage, during the index admission or in a transfer IN, are excluded. The excluding codes are:

ICD-9 dxs 71105,71165,71195,7300,73000,73005,7301,73010,73015,7302,73020,73025,7309,73090,73095.

CPT 27030 Arthrotomy, hip, for infection, with drainage

Pathological Fractures

A candidate case may also be excluded if there is a mention of metastatic cancer or bone cancer on the index admission, or in a transfer in or out. The excluding codes are:

ICD-9 diagnoses:

170	Malignant neoplasm of bone and articular cartilage
1706	Malignant neoplasm of pelvic bones, sacrum & coccyx
1707	Malignant neoplasm of long bones of lower limb
1709	" , site unspecified
1953	" , pelvis
1955	" , lower limb
198	Secondary malignant neoplasm, other spec. sites
1985	Secondary malignant neoplasm of bone and bone marrow
1990	Disseminated malignant neoplasm
7331	Pathologic fracture
73314	Pathologic fracture of neck of femur

CPT codes 27075-9 Radical resection for tumor or infection, pelvis or hip

Codes indicating complications of previous THR

All patients with a code indicating complications of a previous THR during the index admission, in a transfer IN, or (CPTs) within 2 days of the index surgical claim, are excluded. The excluding codes are:

ICD-9 diagnoses (**primary diagnoses only - must be dx1**):

V54.0	aftercare involving removal of fracture plate or other internal fixation device
996.4	mechanical complication of internal orthopedic device, implant & graft
996.6	Infection and inflammatory reaction due to internal orthopedic device, implant & graft
996.60	" due to unspecified device, implant & graft
996.66	" due to internal joint prosthesis
996.67	" due to other internal orthopedic device, implant & graft
996.7	Other complications of internal prosthetic device, implant and graft
996.70	" due to unspecified device, implant & graft
996.77	" due to internal joint prosthesis
996.78	" due to other internal orthopedic device, implant & graft

ICD-9 procedure codes:

78.6	Removal of implanted devices from bone
78.60	" , unspecified site
78.65	" , femur
80.0	Arthrotomy for removal of prosthesis
80.00	" , unspecified site
80.05	" , femur
81.53	Revision of hip replacement

CPT procedure codes:

20680	Removal of implant, deep (e.g., buried wire, pin, screw, metal band, nail rod or plate)
27090	Removal of hip prosthesis; (separate procedure)
27091	" complicated, including “total hip” and methylmethacrylate, when applicable
27134	Revision of total hip replacement; both components, with/without autograft or allograft
27137	" acetabular component only, with/without autograft or allograft
27138	" femoral component only, with/without autograft or allograft

Plurality rules

These rules are meant to prevent a single miscode's being taken at face value. The number of selecting codes for primary THR (ICD-9 procedure 81.51 or CPT 27130) during the index admission, or in a transfer in or out, is counted. This number is compared with the number of possible miscodes (for knee replacement, or for hemiarthroplasty). If the selecting codes are outnumbered by the miscodes, then the case is dropped.

Knee replacement or revision codes

Sometimes a knee replacement or revision is coded as a hip replacement by mistake. The number of codes for knee replacement or revision during the index admission, or in a transfer in or out, are counted. These codes are:

ICD-9 procedure 81.54, 81.55
CPT codes 27437-27447, 27486-27488.

Hemiarthroplasty codes

Sometimes a hemiarthroplasty is coded as a total hip replacement by mistake. The number of codes for hemiarthroplasty during the index admission, or in a transfer in or out, are counted. These codes are:

ICD-9 procedure 81.52
CPT codes 27120, 27125.

Diagnosis flags to describe patients

The following flags use diagnoses in the index admission or in a transfer in or out to describe patients' symptoms.

Degenerative disease

ICD-9 diagnoses 715, 715.0, 715.00, 715.09, 715.1, 715.10, 715.15, 715.2, 715.20, 715.25, 715.3, 715.30, 715.35, 715.8, 715.80, 715.85, 715.89, 715.9, 715.90, 715.95.

Rheumatoid arthritis

ICD-9 diagnoses 714, 714.0.

Aseptic necrosis, non-union

ICD-9 diagnoses 733.4, 733.40, 733.42.

Paget's disease

ICD-9 diagnosis 731.0.

Algorithm for Revision of Total Hip Replacement

July 14th, 1999

Claims from Skilled Nursing Facilities will not be used to define the cohort, but may be used to exclude. NO Outpatient data will be used.

Selecting codes

Select all cases with any of the following CPT codes:

27134 Revision of total hip arthroplasty; both components, with or without autograft or allograft
27137 " ; acetabular component only
27138 " ; femoral component only.

Additional confirming evidence

The following codes serve to confirm a case, if they are found during the same (index) admission:

ICD-9 diagnoses suggesting removal of internal fixation device, mechanical & other complications/infection due to internal prosthetic device, implant or graft:
V54.0, 996.4, 996.6, 996.60, 996.66, 996.67, 996.7, 996.70, 996.77, 996.78.

ICD-9 procedure codes for removal of prosthesis/internal fixation device:
78.6, 78.60, 78.65, 80.0, 80.00, 80.05.
Also
81.53 Revision of hip replacement (partial, total).

CPT procedure codes for removal of implant:
20680, 27090, 27091.

A single surgical claim with a selecting CPT of 27134, 27137 or 27138 and with no confirming evidence is accepted as a case only if the patient was in fact in the hospital on that date, i.e., 3BAs are accepted whereas plain 3Bs are not.

Exclusions

Hip or other femur fractures

Hip/femur fractures are now allowed in the revision cohort.

Conversion of previous hip surgery to THR

All patients with CPT code 27132 during the index admission, in a transfer IN, or within 2 days of the index surgical claim are excluded.

Acetabuloplasty; resection femoral head (Girdlestone procedure)

All patients with CPT code 27122 during the index admission, in a transfer IN, or within 2 days of the index surgical claim are excluded.

Infection of pelvic region and thigh

All patients with a code for Arthropathy associated with infections; Osteomyelitis, periostitis and other infections involving bone; or hip arthrotomy for infection with drainage, during the index admission, or in a transfer IN are excluded from the revision cohort. The excluding codes are:

ICD-9 diagnoses 71105, 71165, 71195, 7300, 73000, 73005, 7301, 73010, 73015, 7302, 73020, 73025, 7309, 73090, 73095.

CPT 27030 Arthrotomy, hip, for infection, with drainage.

NB: Certain codes suggesting infection due to internal prosthetic devices are CONFIRMING - see "Additional confirming evidence."

Pathological Fractures

A candidate case may also be excluded if there is a mention of metastatic cancer or bone cancer on the index admission or in a transfer in or out. The excluding codes are:

ICD-9 diagnoses:

170	Malignant neoplasm of bone and articular cartilage
1706	Malignant neoplasm of pelvic bones, sacrum & coccyx
1707	Malignant neoplasm of long bones of lower limb
1709	" , site unspecified
1953	" , pelvis
1955	" , lower limb
198	Secondary malignant neoplasm, other spec. sites
1985	Secondary malignant neoplasm of bone and bone marrow
1990	Disseminated malignant neoplasm
7331	Pathologic fracture
73314	Pathologic fracture of neck of femur

CPT codes 27075-9 Radical resection for tumor or infection, pelvis or hip

Plurality rules

These rules are meant to prevent a single miscode's being taken at face value. The number of selecting codes for revision (CPTs 27134, 27137 and 27138) during the index admission, or in a transfer in or out, are counted. This number is compared with the number of possible miscodes (for knee replacement, or for hemiarthroplasty). If the selecting codes are outnumbered by the miscodes, then the case is dropped.

Knee replacement or revision codes

Sometimes a knee replacement or revision is coded as a hip revision by mistake. The number of codes for knee replacement or revision during the index admission, or in a transfer in or out, is counted. These codes are:

ICD-9 procedures 81.54, 81.55
CPT codes 27437-27447, 27486-27488.

Hemiarthroplasty codes

Sometimes a hemiarthroplasty is coded as a hip revision by mistake. The number of codes for hemiarthroplasty during the index admission, or in a transfer in or out, are counted. These codes are:

ICD-9 procedures 81.52
CPT codes 27120, 27125.

OUTCOMES AFTER TOTAL HIP REPLACEMENT
June 16th, 1999

Death

This variable comes from the 1995 and 1996 denominator files. Since these files are closed out around March of the following year, we know of a few early-1997 deaths, but for survival analysis it is safest to censor all cases on Dec 31st, 1996. This also aligns the censorship date for all outcomes.

Readmission

The readmission date is the admission date of the first eligible admission after the index (THR) hospitalization. The following types of readmission are NOT counted:

A same-day transfer out of the index hospital.
An admission to a skilled nursing facility.
An admission to a rehab hospital.
An admission with a rehab or aftercare DRG (462, 465, 466).

Musculoskeletal readmission

All of the above applies, but the admission must have a DRG within MDC 8 (Diseases and disorders of the musculoskeletal system and connective tissue).
In 1996, these DRGs were 209-256, 471 and 491.

Pulmonary Embolism (imploded algorithm)

The PE date is the admission date of the first hospitalization with a PE diagnosis, or the "fromdate" of the first institutional O/P claim with a PE diagnosis and other conditions (see below), whichever comes first. NB: PEs occurring in the index (THR) admission ARE counted as outcomes.

Since there were very few patients who had a selecting CPT 33910/33915 (pulmonary embolectomy) and they all had diagnoses of PE, the algorithm simplified into the following:

<u>Selecting ICD-9 dxs</u>
415.1 pulmonary embolism and infarction
415.11 iatrogenic PE & infarction
415.19 other PE & infarction

An INPATIENT diagnosis of PE is sufficient.

If the PE diagnosis is on an OUTPATIENT institutional claim, the following are also required:

A hospitalization (discharge) in the preceding 60 days, AND
A prothrombin time (CPT 85610, I/P or O/P) within 2 days of the PE dx O/P claim, AND
At least one other protime in the following 60 days.

Joint Infection

The infection date is the admission date of the first I/P hospitalization with an infection diagnosis which must be confirmed by a procedure. (The selecting CPT 27030 is sufficient on its own.)
NB: Infection codes in the index (THR) admission cause the case to be excluded from the cohort, so there are no infection outcomes in the index admission.

Selecting ICD-9 diagnoses

711	Arthropathy associated with infections
711.0	Pyogenic arthritis
711.00	" , site unspecified
711.05	" , pelvic region & thigh
711.6	Arthropathy associated with mycoses
711.60	" , site unspecified
711.65	" , pelvic region & thigh
711.9	Unspecified infective arthritis
711.90	" , site unspecified
711.95	" , pelvic region & thigh
730	Osteomyelitis, periostitis, and other infections involving bone
730.0	Acute osteomyelitis
730.00	" , site unspecified
730.05	" , pelvic region & thigh
730.1	Chronic osteomyelitis
730.10	" , site unspecified
730.15	" , pelvic region & thigh
730.2	Unspecified osteomyelitis
730.20	" , site unspecified
730.25	" , pelvic region & thigh
730.9	Unspecified infection of bone
730.90	" , site unspecified
730.95	" , pelvic region & thigh
996.6	Infection and inflammatory reaction due to internal prosthetic device, implant & graft
996.60	" due to unspecified device, implant & graft
996.66	" due to internal joint prosthesis
996.67	" due to other internal orthopedic device, implant & graft

Selecting CPT procedure code

27030	Arthrotomy, hip, for infection, with drainage

Joint infection, continued

Confirming ICD-9 procedure codes

78.6 Removal of implanted devices from bone
78.60 " , unspecified site
78.65 " , femur
80.0 Arthrotomy for removal of prosthesis
80.00 " , unspecified site
80.05 " , hip
80.1 Other arthrotomy
80.10 " , unspecified site
80.15 " , hip
81.91 Arthrocentesis

Confirming CPT procedure codes

20680 Removal of implant, deep (e.g., buried wire, pin, screw, metal band, nail, rod or plate)
26992 Incision, deep, with opening of bone cortex (e.g., for osteomyelitis or bone abscess), pelvis &/or hip joint
27052 Arthrotomy, with biopsy; hip joint
27070 Partial excision (craterization, saucerization) e.g., for osteomyelitis; superficial
27071 " ; deep
27075 Radical resection of tumor or infection; wing of ilium, one pubic or ischial ramus or symphysis pubis
27076 " ; ilium, including acetabulum, both pubic rami, or ischium and acetabulum
27077 " ; innominate bone, total
27078 " ; ischial tuberosity and greater trochanter of femur
27079 " ; " , with skin flaps
27090 Removal of hip prosthesis (separate procedure)

Dislocation

The dislocation date is the admission date of the first hospitalization, or the "fromdate" of the first institutional O/P claim, or the service date of the first physician-supplier claim, with a dislocation procedure code, whichever comes first.
NB: It is difficult to distinguish outcomes from indications in the index admission, and so dislocations in the index admission are not counted as outcomes.

Since a procedure is required and all the procedure codes are specific to dislocation of the hip, any of the following codes are selecting:

Selecting ICD-9 procedure codes:

79.75 closed reduction of dislocation of hip
79.85 open reduction of dislocation of hip

Selecting CPT procedure codes:

27250 Closed treatment of hip dislocation, traumatic; without anesthesia
27252 " ; requiring anesthesia
27253 Open treatment of hip dislocation, traumatic, without internal fixation
27254 Open treatment of hip dislocation, traumatic, with acetabular wall & femoral head fracture, with or without internal or external fixation
27265 Closed treatment of post hip arthroplasty dislocation; without anesthesia
27266 " ; requiring regional or general anesthesia