Preoperative Antibiotics and Mortality in the Elderly

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Objective and Background: It is generally thought that the use of preoperative antibiotics reduces the risk of postoperative infection, yet few studies have described the association between preoperative antibiotics and the risk of dying. The objective of this study was to determine whether preoperative antibiotics are associated with a reduced risk of death.

Methods: We performed a multivariate matched, population-based, case-control study of death following surgery on 1362 Pennsylvania Medicare patients between 65 and 85 years of age undergoing general and orthopedic surgery. Cases (681 deaths within 60 days from hospital admission) were randomly selected throughout Pennsylvania using claims from 1995 and 1996. Models were developed to scan Medicare claims, looking for controls who did not die and who were the closest matches to the previously selected cases based on preoperative characteristics. Cases and their controls were identified, and charts were abstracted to define antibiotic use and obtain baseline severity adjustment data.

Results: For general surgery, the odds of dying within 60 days were less than half in those treated with preoperative antibiotics within 2 hours of incision as compared with those without such treatment: (odds ratio = 0.44; 95% confidence interval, 0.32–0.60), $P <$ 0.0001). For orthopedic surgery, no significant mortality reduction was observed (OR = 0.85; 95% confidence interval, 0.54–1.32; $P <$ 0.464).

Interpretation: Preoperative antibiotics are associated with a substantially lower 60-day mortality rate in elderly patients undergoing general surgery. In patients who appear to be comparable, the risk of death was half as large among those who received preoperative antibiotics.

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Elderly patients undergo millions of general surgical and orthopedic procedures each year. Each procedure is associated with a decision: should preoperative antibiotics be administered or not. The purpose of this study was to determine whether the use of preoperative antibiotics is associated with a reduced risk of death. Although guidelines suggest that preoperative antibiotics are often recommended and numerous reports have described the benefits of preoperative antibiotic use with respect to preventing postoperative infection,[1–10] almost no studies have estimated the reduced risk of death associated with lack of preoperative antibiotic use.[2]

Since postoperative death rates are generally low in orthopedic and general surgery,[11,12] the inability to obtain a large sample of deaths may preclude any one institution from fully appreciating the possible risks associated with omitting preoperative antibiotics. Although there are numerous randomized clinical trials concerning preoperative antibiotic use in the literature, none has been large enough to assess differences in mortality across treatment groups,[1,13] and almost none has reported mortality rates as an end-point.[2]

The Surgical Outcomes Study[11,14,14a] is an attempt to better understand the association between caregiver actions and mortality, and its design has been published elsewhere.[11] Here we report initial results from the Surgical Outcomes Study study utilizing a matched, population-based, nested case-control design (or synthetic case-control study,[15]) to estimate the relative odds of mortality associated with the use of preoperative antibiotics, adjusting for detailed medical data found in the patient's chart.

METHODS

Patients and Databases

Medicare data represent the most representative sample of healthcare data in the United States because Medicare is an

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entitlement. The only substantial group of citizens not represented in the Medicare claims data are those who opt out of the Medicare fee-for-service arrangement and joined a Medicare-approved prepaid health maintenance organization (HMO). Case-control sampling of the Medicare population was needed because it is far too expensive to obtain and abstract hospital charts for every Medicare patient, but it is feasible for a sample. We obtained the Medicare Inpatient (Part A), Outpatient Standard Analytic Files, and Physician Part B files for all general and orthopedic surgical Diagnosis Related Groups (DRGs) in Pennsylvania between 1991 and 1994, and for the years 1995 to 1996. These files represent the fee-for-service Medicare population, comprising approximately 90% of all beneficiaries for 1995 to 1996.[16,17] For each patient, we created a longitudinal record by including all inpatient and outpatient claims and physicians' claims during that time interval. Data also included the Medicare Vital Status File, American Hospital Association Annual Surveys for 1996, and the Pennsylvania Health Care Cost Containment Council (PHC4) Hospital Discharge Database for similar years, which included the MedisGroups (MediQual, Inc., Marlborough, MA) severity score to supplement the Medicare record.[18] Medicare stores electronically all bills submitted by hospitals and physicians and all other caregivers, and stores all payments made. This billing data include limited diagnosis codes collected using ICD9-CM coding and other procedure-specific codes.

Definitions

A case was defined as a Pennsylvania Medicare patient treated between the ages of 65 to 85 years in Pennsylvania between the years 1995 to 1996 who died of any cause within a 60-day period from admission. We used death by 60 days from admission because we found that after 60 days the hazard rate for death was less than half as large as the hazard between 30 and 60 days.[11,14] A control was a patient who survived greater than 60 days from admission and who was closest in characteristics to the case on admission, based on a multivariate matching algorithm, which is described below.

Model Development and the Multivariate Matching Algorithm

Using multivariate techniques described in Silber et al,[11,14a] Rosenbaum and Rubin,[19,20] and Rubin,[21,22] deaths were matched to survivors based on 51 Diagnosis Related Group (DRG)/principal procedure variables and 32 other prognostic variables, so the case and control groups appeared comparable upon admission in terms of these variables. A very brief summary of the matching procedure follows; see Silber et al[11] for details. First, in this case-control study, we drew a random sample of deaths or cases from all Medicare patients aged 65 to 85 years who were operated on between 1995 and 1996 for one of the study procedures. Each death was matched to a survivor who appeared similar upon admission to the hospital. Specifically, using data from earlier years, we built a logistic regression model predicting death from patient characteristics, and then used this model to estimate the probability of death for each case and each potential control. Using an optimization procedure, we matched deaths to survivors as closely as possible for estimated risk of death, presence of cancer and certain cancer

TABLE 1. Dead Cases and Matched Surviving Controls: Matched Patient Characteristics Based on the Medicare Claims Data

	Cases	Control
No. of Patients	681	681
Demographic variables		
Age (yr) (mean)	77	77
Sex (% male)	46	42
Race (% white)	93	93
Race (% black)	5	5
Admission from Emergency Department (%)	57	57
Transfer in (%)	2	1
MedisGroups Severity Score of 3 or 4 (%)	35	35
Probability of death* (%)	15.6	15.5
History variables		
Cancer (%)	47	47
Hypertension (%)	45	45
COPD (%)	29	28
Diabetes (%)	27	26
Arrhythmia (%)	20	16
CHF (%)	18	17
Renal failure (%)	8	7
Liver abnormalities (%)	6	7
MI (%)	6	7
Procedures		
Orthopedic (%)	38	38
Hip (%)	30	30
Knee (%)	0.4	0.4
Shoulder (%)	0.3	0.3
Back (%)	2.4	2.4
Other (%)	5.3	5.3
General Surgery (%)	62	62
Colon resection (%)	29	29
Stomach procedure (%)	9.8	9.8
Other digestive (%)	13	13
Gallbladder (%)	4.9	4.9
Hepatobilliary (%)	1.9	1.9
Other General Surgery (%)	2.9	2.9

*Estimated probability of death at admission from a logistic regression model based on 32 patient covariates and 51 DRG/procedure groups based on parallel but separate Medicare claims data from earlier years.

types, and other key variables. As seen in Table 1 and in more detail in Silber et al,[11,14a] the matching was very successful at balancing variables available for matching from Medicare. We then abstracted charts for the matched pairs, learning much more about each patient.

Chart Abstraction

Random sampling and matching using Medicare data yielded the charts for abstraction. Once abstracted, the charts provided further baseline information, including a physiology score based on selected variables included in the APACHE[23,24] severity algorithm. These variables were then used as an adjustment in the conditional logistic regressions[25] to estimate the odds of death given the use of preoperative antibiotics.

There were a total of 186 hospitals represented in the study, with a mean of 7.3 charts per hospital (median, 6 charts; range, 1–26 charts). Chart abstraction was completed by the Medicare Clinical Data Abstraction Center, DynKePRO, Inc., as a subcontract with KePRO, the Pennsylvania Peer Review Organization. Abstraction time frames included admission, day of and day after surgery, and the day before, day of, and day after the first complication diagnosis. Admission variables included comorbidities, consciousness assessment, preoperative labs (albumin, bilirubin, BUN, creatinine, glucose, hemoglobin, platelets, potassium, sodium, urine blood or protein), and vital signs. During the first operation, vital signs, pulse oximetry results, and pertinent negative events were gathered. This information was also collected in the recovery room.

Defining Preoperative Antibiotic Use

Preoperative antibiotic use was defined using 2 sections of the medical record. For all antibiotics administered during the first 21 days of the hospitalization, we recorded the start and end dates and the start time for each drug as it appeared in the medication administration record. This process was used for all drugs given on the floor. Antibiotic information was also obtained from the anesthesia record and the operative report for patients who received antibiotics in the surgical suite that were not documented in the medication administration record. For these cases, abstractors were instructed to code yes to “preoperative antibiotics” if any antibiotics were administered within 2 hours prior to the surgical incision, as recorded in the anesthesia or operative record.

Statistical Methods

Once charts were abstracted for dead cases and their matched surviving controls, we obtained much more detailed information about the health of patients prior to surgery, as well as detailed information about antibiotic use. Our analysis incorporates this information using McNemar’s test[26] and conditional logistic regression, which attempts to predict who will die and who will live within a matched pair using differences in prognostic variables within pairs.[27]

Diagnostic checking of the conditional logit model consisted of fitting more complex models to search for improved fit. When reporting subgroup analyses, we generally used a dummy variable interaction approach that allowed for all 1362 patients to remain included in the model, while testing hypotheses regarding relevant subpopulations.

Matched Pairs

Of 1578 potential charts for abstraction, 120 were disqualified for analysis: 5 abstractions occurred on the wrong chart; 33 charts were incomplete and lacked necessary data, and 82 charts did not involve surgery with general anesthesia within the first 21 days of admission (usually because these patients underwent bedside procedures without general anesthesiology and were not eligible for analysis). This left 1458 charts that qualified for review. We lost another 96 charts that were orphaned (the case was missing its control or the control was missing its case). Hence, the final sample consisted of 681 cases (deaths) and 681 matched controls (alive) available for analysis.

RESULTS

Matching Description

We report the quality of the matched pairs according to 2 main sets of variables: those variables that were used in the matching algorithm (Table 1) and those variables that were collected from chart information not available for the initial claims based multivariate matching algorithm (Table 2). The matched variables in Table 1 included major comorbidities, demographic variables, procedure groupings, and a model-based estimate of the initial probability of death. The matching was highly successful: the deaths and survivors were very similar upon admission in terms of variables available in the Medicare data. Both our dead cases and our surviving controls had a 16% chance of death based on their condition upon admission, whereas the entire population of unmatched Medicare survivors had less than a 5% chance of death.[11] However, there was considerable variability across matched pairs, with 25% of cases and controls having a 6% or less probability of death on admission.

Chart abstraction for matched pairs produced a wealth of data not available from Medicare claims, including a physiologic based severity score approximating the APACHE severity score,[23,24] and individual measures of body mass index, serum sodium, serum albumin, and blood pressure. In Table 1, matching on Medicare data is seen to produce pairs comparable in terms of these data, but in Table 2, once charts were abstracted, substantial differences were found across these new unmatched variables, differences that we controlled for by including them in the conditional logistic model.[14a]

TABLE 2. Unmatched Patient Characteristics That Were Not Available for the Original Matching Algorithm Since Claims Data Did Not Include These Variables

	Case	Control	*P*†
BMI underweight (BMI < 18.5) (%)	15.0	7.6	0.0001
BMI obese (BMI > 30) (%)	11.8	14.1	NS
Baseline APACHE approximation (mean)	15.5	12.7	0.0001
Low mean blood pressure (BP < 75 mm Hg) (%)	6.5	3.5	0.014
High mean blood pressure (BP > 120 mm Hg) (%)	20.9	27.5	0.003
Sodium low (Na < 129 mg/dL) (%)	3.7	3.4	NS
Sodium high (Na > 150 mg/dL) (%)	1.0	0.7	NS
Albumin low (albumin < 2.4)	9.7	4.3	0.0001
Preoperative complications (%)	38.6	26.0	0.0001
Preoperative ICU stay (%)*	5.4	3.7	NS
BUN (g/dL) (mean)*	26	24	0.006
Creatinine (g/dL) (mean)*	1.4	1.4	NS
Hematocrit*	40.6	40.9	NS
Bilirubin total (g/dL) (mean)*	1.0	0.7	0.003
Glucose (g/dL) (mean)*	148	144	NS

Differences seen here were controlled using conditional logistic regression (see Table 4). NS, not significant.

*Variable included in the conditional logistic regression model as part of the Baseline APACHE approximation. Age and sex were also included in the adjustment model.

†A McNemar test was used for categorical data and a paired Wilcoxon signed rank test was used for continuous variables.

Main Findings

Results of the Unadjusted Matched Pair Analysis

Tables 3 and 4 display the 681 matched pairs according to survival at 60 days from admission, and according to whether or not preoperative antibiotics were administered within 2 hours of incision. These matched pairs reflect the adjustments presented in Table 1, but are not adjusted with the variables in Table 2. There was a strong association between preoperative antibiotics administered within 2 hours of incision and survival. The odds of dying with antibiotics were about half those of dying if no antibiotic was administered within 2 hours (104 of 186 = OR = 0.56, 95% CI 0.44–0.71, McNemar's Test *P* value <0.00001).

TABLE 3. Unadjusted Results of Preoperative Antibiotics Within 2 Hours of Incision (*N* = 1362 patients)

	Preoperative Antibiotics		
	Yes	No	Total
Dead	411	270	681
Alive	493	188	681
Total	904	458	1362

Results of the Conditional Logistic Model

Despite the closeness of the matches as described in Table 1, addition of the chart data described in Table 2 predicts survival. Including the 11 new variables produced a significant improvement in the model (likelihood ratio $\chi^2 = 52.7$ on $df = 11$ degrees of freedom, *P* value <0.0001). Among these variables, poor health, as judged by the APACHE approximation physiologic score, low body mass

TABLE 4. Unadjusted Results of Preoperative Antibiotics Within 2 Hours of Incision (*N* = 681 Matched Pairs) (*N* = 681)

	Alive	
Dead	Antibiotics Yes	Antibiotics No
Antibiotics Yes	307	104
Antibiotics No	186	84

Each cell in Table 4 represents the number of matched pairs, containing 1 case (death within 60 days of admission) and 1 control (a patient who survived 60 days postadmission). The odds of death associated with receiving antibiotics within 2 hours of incision were almost half as large as those who did not get antibiotics within 2 hours of incision: 104 of 186 = OR = 0.56; 95% CI, 0.44–0.71, McNemar's Test, *P* value <0.00001). These are unadjusted results. Adjustments were accomplished using chart based information and the development of conditional logistic models.

TABLE 5. Results of the Conditional Logistic Models Predicting Death at 60 Days From Admission Based on Receiving Preoperative Antimicrobial Prophylaxis Within 2 Hours of Incision by Surgical Group

	N	With Preoperative Antibiotics (N)	Odds Ratio*	95% CI	*P*
General and Orthopedic Surgery	1362	904	0.55	0.42–0.71	0.0001
General Surgery (all groups)	840	523	0.44	0.32–0.60	0.0001
Stomach	134	90	0.27	0.09–0.76	0.012
Colon	392	245	0.44	0.28–0.71	0.0006
Other digestive procedures[†]	182	118	0.36	0.18–0.72	0.004
Gallbladder	66	35	0.72	0.25–2.10	0.54
Hepatobilliary procedures[‡]	26	14	0.23	0.02–2.35	0.22
Other General Surgery[§]	40	21	0.94	0.30–2.91	0.92
Orthopedic Surgery	522	381	0.85	0.54–1.32	0.47

All models adjusted for the same 11 baseline variables as described in Table 2.

*Odds of death with antibiotics by odds of death without antibiotics from the logistic model.

[†] Other Digestive includes procedures of the small and large bowel, peritoneal procedures, hernias, appendectomies, and anal and stomal procedures.

[‡] Pancreas, liver and shunt procedures, and biliary tract procedures.

[§] Other General Surgery includes amputations, mastectomies, skin, and endocrine procedures.

index, and preoperative complications, were significantly associated with greatest increased odds of death.

Adjusted Results

Table 5 provides results of a matched conditional logistic model adjusting for the variables noted in Table 2. The addition of interaction terms involving the physiology score, a variable for being underweight, having low albumin, and the development of preoperative complications did not change these results. Furthermore, Table 5 displays results across different types of surgery. All models described in Table 5 use all 1362 patients, but some models incorporate interaction terms to estimate the effects of antibiotics separately for different types of surgery. Here we can see that type of surgery did matter: the largest declines in mortality associated with antibiotics were found among stomach, colon, other digestive procedures, and possibly hepatobilliary procedures, although this last group was small and the effect not statistically significant.

Stability of Results in Alternative Analyses

To check on the stability of our findings a variety of parallel analyses were performed as described below:

Prior Antibiotics and Preoperative Antibiotic Use

The question arises whether failure to receive preoperative antibiotics within 2 hours from surgery could be a proxy for sicker patients already receiving antibiotics, possibly explaining their worse outcomes. Hence, we estimated the effect of preoperative antibiotics only in those patients who were not on other antibiotics prior to surgery. Again, our model was fitted to all 1362 patients, but it estimated effects in subgroups using interaction terms. Our results were very similar. In patients not previously on antibiotics during the 24 hours prior to surgery ($N = 1100$), the adjusted odds ratio for death associated with preoperative antibiotics in general surgery was 0.43 (95% CI 0.29–0.62), $P < 0.0001$. For orthopedic surgery, the odds ratio was 0.88 (95% CI 0.54–1.43), $P = 0.60$.

Controlling for Hospital Differences

Another obvious concern is that the use of preoperative antibiotics might be standard practice in hospitals that provide generally better care, so perhaps this better care, not antibiotics, caused the better survival of patients receiving antibiotics. This initially plausible concern is clearly contradicted by the data. We refit the model displayed in Table 5 with a model including indicator variables for each hospital that had at least 5 patients in the study. The indicator variables reflect and adjust for systematic differences in care between hospitals. Again, these results were very similar to those reported in Table 5. In our study, 83% of the patients were in hospitals that treated at least 5 patients, and there were 104 such hospitals. We added 104 hospital indicator variables to our model to adjust for variations in practices among these hospitals and re-estimated the effect of antibiotics. This adjustment augmented the beneficial effects of preoperative antibiotics. The OR for all surgical types combined was now 0.47 (95% CI 0.34–0.64), $P < 0.0001$, as compared with 0.55 previously. Therefore, it does not appear that differences among hospitals can account for the antibiotic effect seen in Table 5.

As an alternative analysis, we adjusted for characteristics of the hospitals, rather than using hospital indicators. We added 9 hospital characteristics to the models presented in Table 5: hospital size, medical school affiliation, residency program, trauma center, the presence of an organ transplant unit, the presence of a magnetic resonance facility, the patient to nurse ratio, the nurse to registered nurse ratio, and the volume of Medicare patients undergoing general surgery or orthopedic surgery for each hospital. The findings did not change. The odds ratio for death associated with preoperative antibiotics was 0.53 (95% CI 0.40–0.69), $P < 0.0001$.

Controlling for Differences Across Surgeons

Perhaps physicians who do not use prophylactic antibiotics have higher mortality rates because the care they deliver is inadequate in other ways. To assess this possibility, we estimated a mortality rate for each physician using the full set of 114,452 patients in the statewide data set, not including the patients in our matched study. For each surgeon, we calculated the observed proportion of deaths minus the expected proportion of deaths based on the probability of death as defined previously[11] to create a measure of underlying quality of care. If this observed-minus-expected rate was positive, it signified that the surgeon had a higher mortality rate than one would predict based on the characteristics of the patients this surgeon treated. When this measure was placed in the model described in Table 5 for general surgical and orthopedic patients, we found no change in the results (OR = 0.54; 95% CI 0.42–0.70), $P < 0.001$. Antibiotic use is associated with lower mortality whether or not the surgeon's mortality rate is above or below the expected rate.

Controlling for Differences Among Operations

Since we might expect patients operated on between 6 PM to 6 AM to be at increased risk either because inadequate staffing or urgent conditions, we tested whether the 164 patients operated on during this evening time interval could account for the beneficial effect of antibiotics. While evening patients were at increased risk of death with OR = 1.59 (95% CI 1.09–2.28), $P < 0.001$, the beneficial association with antibiotic use was unchanged (OR = 0.54; 95% CI 0.42–0.70), $P < 0001$). Furthermore, our results were the same after we adjusted for weekends and holidays that also might be associated with inadequate staffing. We also looked at the duration of the procedure and adjusting for this variable, again, our results were virtually unchanged (OR = 0.54; 95% CI 0.42–0.70), $P < 0.0001$.

Refined Adjustments for Principal Procedure and Patient Comorbidities

To be sure that differences in specific procedures, or differences in comorbidities, were not responsible for our findings, we added the principal procedure and patient comorbidities from the Medicare claims into the conditional logistic model and found no difference in our results. The odds ratio for death associated with preoperative antibiotics was 0.50 (95% CI 0.38–0.67), $P < 0.0001$.

Lack of Preoperative Antibiotics as a Marker of a Time-Pressured Case

We further explored the possibility that the beneficial effects of antibiotics were a marker for less urgent care as opposed to emergency or direct admit cases where physicians may have had no time to administer antibiotics. In other words, could it have been the case that not receiving preoperative antibiotics was a marker of a more severely ill patient, and due to time-pressure, antibiotics were not administered? Since we had chart abstraction data, not just claims, we could distinguish between direct admission cases, admissions from the emergency room, and elective cases. Furthermore, we could analyze our results using the actual time from admission to incision.

We defined a "rushed" general surgical operation as follows: 1) the patient entered the hospital through the emergency room or by direct admission, and 2) the operation took place within 12 hours of admission. Other patients were "not rushed." We then estimated the association between mortality and antibiotics separately for "rushed" and "not rushed" patients. Among "not rushed" patients, the odds ratio was 0.49 (95% CI 0.34–0.69), $P < 0.001$, whereas among "rushed" patients the odds ratio was 0.22 (95% CI 0.09–0.52), $P < 0.001$. Hence, there appears to be a strong association between preoperative antibiotics and mortality whether or not the patient was in the rushed category.

We also looked at "elective" general surgery patients, although they were a small part of our total sample. Recall that our entire patient group of 1362 patients consisted of 681 deaths together with matched survivors who appeared to be in similar health upon admission. Not surprisingly in this study population, only 331 of 1392 patients, or 24%, had elective procedures. Of the 840 general surgical patients, 614, or 73%, were admitted either through the emergency room or by direct admission. There were only 62 general surgical elective patients without preoperative antibiotics and 164 with preoperative antibiotics. Estimating the association between mortality and antibiotics separately for these patients gave an odds ratio 0.82 (95% CI 0.43–1.55). Here the association is neither strong nor statistically significant.

Sensitivity to Unobserved Covariates

Although our analysis has made extensive efforts to adjust for differences in the initial health of patients, the possibility always remains that patients receiving preoperative antibiotics differed from those who did not in ways we did not observe. It is possible, at least in principle, that surgeons use some prognostic variable we did not measure to selectively deny antibiotics to their sickest patients, thereby producing a spurious association between mortality and antibiotics. A sensitivity analysis indicates what such an unobserved prognostic variable would have to be like to alter the substantive conclusions.[28] Failure to adjust for an unobserved prognostic attribute that doubled the odds of antibiotic use and also halved the odds of death would still yield a highly significant effect ($P < 0.003$) by McNemar's test applied to Table 2, while a tripling of the odds of antibiotic use and a halving the odds of death would still yield a significant ($P < 0.04$) effect.[29] However, failure to adjust for an unobserved attribute that tripled the odds of antibiotic use and reduced the odds of death by two thirds could explain the observed association ($P > 0.5$). If surgeons were only one third as likely to give antibiotics to patients who were at 3 times the risk of death, then this curious behavior could explain away the association we found between antibiotics and mortality; however, we found no data to support this possibility.

Infections and Related Complications

In an effort to understand the mechanism for the dramatic reduction in 60-day risk of death associated with preoperative antibiotics, we closely examined the chart abstraction data. Our case-control study identified deaths following surgery and matched controls using Medicare data, then abstracted hospital charts for these patients. The data on infections are from the charts themselves, not from Medicare, so that data from the charts could not be used to determine which charts to abstract. Hence, the patients in our study died of widely varied causes, not typically infections, so the data on infections just after surgery involve small numbers of patients, being merely suggestive of hypotheses deserving further investigation. It is important to note that an association between mortality and preoperative antibiotics was apparent only among the patients receiving General Surgery. For example, among the 420 General Surgical patients who died, just slightly more than half (223, or 53%) received preoperative antibiotics. In sharp contrast, among the 7 patients who died with perforation, only 2 (28%) had received preoperative antibiotics. Among the 18 patients who had died with peritonitis, 8, or 44%, had received preoperative antibiotics. Of the 2 patients who died with heart valve complications, 1 underwent a rectal resection and the other underwent a suturing of a gastric ulcer, both without preoperative antibiotics. However, we did not find a deficit of patients receiving antibiotics among those who died following deep wound infections. Deep wound infections vary considerably in their severity, so this lack of association may have been due to our inability to assess the severity of these complications.

DISCUSSION

While it has been known that preoperative antibiotics aid in the prevention of surgical site infections,[11] their influence on mortality has not been well defined. We found a strong association between use of preoperative antibiotics and lower 60-day mortality. It is not a surprise, however, that this strong association has not been previously recognized. The estimates of decreased odds of death associated with preoperative antibiotic prophylaxis could not be made at any single institution, as there would be too few deaths associated with any single type of patient to allow for stable estimates of these risk parameters. Claims data alone, while providing large numbers of patients, do not contain the required clinical data, for example, the timing of antibiotics. The association between mortality and antibiotics that we found required chart abstraction from a large case-control study with many hundreds of deaths. The fact that this association has never been studied may explain why we found that fully one third of our sample did not receive preoperative antibiotics.

Our results were consistent with 2 central features of the literature on antibiotic prophylaxis: 1) antibiotics should be administered so that peak concentrations occur at the time of incision and during the operation;[1,3] and 2) the benefits to antibiotic prophylaxis depend on the type of surgery being performed.[1,13] Although we did not find a significant effect on mortality in orthopedic procedures, this does not imply that preoperative antibiotics are not important, as such treatment may reduce infections when implanting a foreign body,[1,13,30–33] and we may not have had adequate power to detect the benefit of preoperative antibiotics in this subgroup. Furthermore, the full risks and benefits of preoperative antibiotic use must always be considered. For example, elderly patients are more susceptible to antibiotic-induced *Clostridium difficile* infections,[34] and risks associated with drug resistance must also be must considered.

The lower risk of death associated with preoperative antibiotics does not appear to be a hospital or physician effect. Within a given hospital, antibiotic use is still strongly associated with lower mortality. Also, we determined the surgeon's mortality rate for patients outside of this study over a 2-year period. When adjusting for this measure of the quality of the surgeon, antibiotic use was still strongly associated with lower mortality. Our analyses suggest that, in good or bad hospitals, with good or bad surgeons, preoperative antibiotics are associated with lower mortality.

CONCLUSION

Preoperative antibiotics given within 2 hours of the incision are associated with a 50% lower risk of 60-day mortality in elderly general surgery patients. This study provides strong support to guidelines suggesting that patients undergoing surgery on the colon, stomach, and small bowel receive preoperative antibiotics.

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