Monitoring adverse outcomes of surgery using administrative data

by Leslie L. Roos, Noralou P. Roos, and Sandra M. Sharp

In this article, we document a stabilization in adverse outcomes associated with hysterectomies, cholecystectomies, and prostatectomies performed between 1972-73 and 1982-83 in Manitoba, Canada. The proportion of surgery performed by high-volume surgeons and by surgical specialists increased slightly over the decade. However, given the already low rates of adverse outcomes, these changes did not translate into significant decreases in the postoperative mortality rate or in the rate of related hospital readmissions. Reducing the proportion of adverse outcomes would be facilitated by identifying institutions with poorer than expected outcomes.

Introduction

Since the early 1970's, Manitoba, Canada, the site of the research project discussed in this article, has experienced a centralization of high-risk procedures and a limitation of the surgical privileges of nonspecialists. Quality of care has been generally assumed to improve with more experienced practitioners providing it (Moore, 1975). For certain operations, a link between lower surgical mortality rates and greater hospital experience with the procedure (higher volume) has been demonstrated (Riley and Lubitz, 1985; Luft, Bunker, and Enthoven, 1979; Showstack et al., 1987).

This study monitors adverse outcomes of surgical care delivered in the Province of Manitoba during the period 1972 through 1983. Experience with three common surgical procedures—hysterectomy, cholecystectomy, and prostatectomy—is highlighted. In this article, we examine both the experience of hospitals and physicians performing the surgery and several widely accepted outcome measures: postsurgical mortality, hospital readmissions for any reason in the immediate discharge period, and readmissions associated with specific complications of the surgical procedure. This research is population based and includes all surgery, whether performed in the most sophisticated teaching hospitals or in small rural hospitals in the remote northern areas of the province.

First, changes in the frequency of these surgical procedures are presented for three 2-year cohorts: all people operated on during calendar years 1972-73, 1977-78, and 1982-83. Data on the case-mix characteristics of these surgical cohorts are then reviewed because changes in outcomes of care are difficult to assess in the absence of knowledge of the types of individuals undergoing surgery. Rates of adverse outcomes in the three surgical cohorts are discussed. Finally, analyses to identify institutions with outcomes that should be reviewed are presented.

Methods

In Manitoba, all medical and hospital care (with a few minor exceptions such as private room and cosmetic surgery) costs nothing to the patient, and there is no usage limitation. A complete history of hospitalizations and surgery can be reconstructed for each individual from claims data. Because out-of-province medical care is reimbursable by the Manitoba Health Services Commission and physicians operate under a fee-for-service system, both physician and patient have an incentive to document utilization. The validity and reliability of the Manitoba claims data have been investigated extensively (Roos et al., 1982). In a few cases (1.5-2.0 percent), various types of identifier problems make it difficult to trace individuals through time. Overall, however, longitudinal followup is very good, comparing favorably with that in studies based on primary data collection (Roos, Nicol, and Cageorge, 1987).

Individuals were included in this study if they had one of the three major surgical procedures as their primary operation. The technical note contains relevant codes from the *Eighth Revision International Classification of Diseases, Adapted for Use in the United States*, ICDA-8 (National Center for Health Statistics, 1967) and *International Classification of Diseases, 9th Revision, Clinical Modification*, ICD-9-CM (Public Health Service and Health Care Financing Administration, 1980) as well as details on case selection. The major groups of patients excluded from all analyses were those with associated malignancies (that is, prostate or bladder malignancy in the case of prostatectomy, malignancies of the gallbladder or pancreas in the case of cholecystectomy, and malignant neoplasms of digestive organs, uterus, and lymphoid tissues in the case of hysterectomy). Over the decade, the proportion of cases excluded increased somewhat. Thus, in 1972-73, 4.1 percent of the cholecystectomies were excluded, compared with 5.6

This research was supported by Career Scientist Awards (6607-1314-48 to Leslie L. Roos and 6607-1101-22 to Noralou P. Roos) and a grant (6607-1197-44) from the National Health Research and Development Program. The authors are indebted to the Manitoba Health Services Commission, which helped make this research possible. Interpretations of the data are the authors' own and do not necessarily represent the official opinion of the Manitoba Health Services Commission or Health and Welfare Canada.

Reprint requests: Leslie L. Roos, Faculty of Medicine, University of Manitoba, Winnipeg, Manitoba, Canada R3T2N2.

percent in 1982. The proportion of hysterectomies excluded rose from 6.9 percent to 11.0 percent, and the proportion of prostatectomies excluded grew from 21.5 percent to 25.9 percent. Inclusion of these malignancies in the analysis produced considerably higher mortality rates but few changes in trends over time. In analyses for which inferences might be changed, results with malignancies included are incorporated in the text.

Both a hospital's surgical volume and a surgeon's experience were measured by the number of relevant procedures performed annually. Physician and hospital counts for surgical volume were made using all procedures, including those for malignancies. On the basis of previous analyses (Roos et al., 1986), high-volume hospitals and surgeons were defined as follows: for hospital volume, 200 or more of the relevant procedure over a 2-year period; for surgeon volume, 40 or more hysterectomies or cholecystectomies and 100 or more prostatectomies. The specialty of physicians performing surgery indicated their surgical qualifications. In Canada, only board-certified physicians can list themselves as specialists; for example, a board-eligible but not board-certified gynecologist would be listed as a general practitioner.

Outcomes of care

Three measures were used for studying outcomes associated with surgery:

- Postsurgical mortality rates (deaths within specified time periods, whether they occurred in or out of a hospital).
- Readmissions to a hospital for any reason within a specified time period.
- Readmissions up to 15 months after the primary procedure for complications specifically associated with the primary surgery.

Transfers from the hospital where surgery took place to another hospital were not included in the readmission analyses.

Deaths were identified from the registry files of the Manitoba Health Services Commission (MHSC). These files have been extensively checked against mortality data from the Office of Vital Statistics, and the overall reliability of the MHSC data is quite high (Wajda and Roos, to be published). However, some deaths are known to be missing from the registries for the early 1970's, a period when records were not routinely obtained from the Office of Vital Statistics.

In this study, computer-based algorithms were used to identify complications leading to rehospitalization in the 15 months following the primary procedures. These algorithms were developed in several stages. For each procedure, a research nurse prepared claims-based presurgical and postsurgical histories for all patients admitted in 1974 who were suspected of having a postsurgical complication, using liberally interpreted literature guidelines. Initially, a large number of "possibles" (approximately 80 percent more cases than were eventually chosen) were selected. These histories were then presented to two physician specialists, who independently judged whether the readmissions were for surgery-related complications. Comparing initial independent ratings characteristically generated kappa values of .4 to .6. Then the physicians met to resolve differences; the final decisions by the two physicians produced kappa values in the range of .7 to .8. Only complications agreed on by both physicians were retained in our computer-based analysis.

The initial set of computer-based algorithms was developed using guidelines from the literature, physician input, and 1974 hospital claims. These algorithms were then modified using 1975 data and finally tested with 1976 data. The computerized algorithms were compared with the clinical decisions of the physician pairs. The results showed high specificity, sensitivity, and predictive values (characteristically greater than .90). A complete listing of the ICDA-8 and ICD-9-CM codes associated with these complications is contained in Roos et al. (1985).

Although the validity and reliability of this approach has been carefully tested, computerized algorithms had not previously been applied over a time period spanning a change in diagnostic coding practices (for example, from ICDA-8 to ICD-9-CM). Several methods for overcoming possible coding differences were applied. We obtained from the Manitoba Health Services Commission their one-to-one conversion table, which was then carefully reviewed by a research nurse skilled in International Classification of Diseases diagnostic coding. Significant differences were flagged and incorporated into our coding system (reported in Roos et al., 1985). The final coding algorithm was tested empirically by comparing counts for specific types of complications across the two coding periods. If gross discrepancies were apparent, detailed examination and changes in the codes included and excluded were made. Only three cases (less than .01 percent) were so affected. Finally, the number of readmissions for any reason in the 1-42 day and 43-90 day periods following surgery was used as an outcome independent of the coding issues.

Type of surgery and risk factors

Studying variation in quality of care over time is difficult without information on changes in patient mix and changes in type of surgery. Increased surgery on higher risk patients or the performance of more risky (or less risky) surgery could interact with changes in the quality of care. For example, gallbladder surgery that includes bile duct exploration is associated with higher mortality rates and higher readmission rates than is simple cholecystectomy (Roos and Danzinger, 1986; Fink, 1986; Henry and Carey, 1983). Prostatectomies performed using the transurethral approach have been associated with a higher revision (reoperation) rate (Wennberg et al.,

1987) and, in some studies, with a lower mortality rate (Chilton et al., 1978). Having multiple diagnoses at the time of the operation or certain specific diagnoses (cancer other than that of the target organ, chronic ischemic heart disease, or congestive heart failure) increases the risks associated with surgery.

Results

Over the 10-year period, the numbers and age-sex-adjusted rates of hysterectomy and cholecystectomy decreased, the latter rather dramatically. Slightly more than one-half as many cholecystectomies were performed in 1982-83 as in 1972-73 (Table 1).[1] In the early 1970's, Manitoba cholecystectomy rates were considerably higher than those in the United States; the drop made the Manitoba rates only slightly higher by the late 1970's (Mindell, Vayda, and Cardillo, 1982; Rutkow and Zuidema, 1981). In the United States, rates of both hysterectomy and cholecystectomy increased slightly from 1979 to 1983 (Rutkow, to be published). The number and rate of prostatectomies performed in the province stayed approximately the same over the decade 1972-73 to 1982-83. The number of prostatectomies in the United States increased markedly from 1979 to 1983, from 293,000 to 357,000 (Rutkow, to be published).

Changes both in the types of patients coming to surgery and in the types of procedures performed are shown in Tables 2-4. The age of women undergoing hysterectomies changed only slightly, with a drop in the percentage of patients aged 45-54 years (from 36.0 percent in 1972-73 to 28.6 percent in 1982-83) and an increase in the percentage aged 55 years or over (Table 2). Over the same period, the proportion of women with multiple diagnoses at the time of surgery decreased, and the percentage of vaginal procedures performed dropped slightly.

The large drop in the cholecystectomy rate from 1972-73 to 1982-83 was accompanied by several changes in case mix. The proportion of patients aged 75 years or over increased (from 5.2 percent in 1972-73 to 9.0 percent in 1982-83), and the proportion of persons with multiple diagnoses at the time of surgery grew slightly (Table 3). The proportion of procedures including common bile duct exploration rose from 8.9 percent to 11.6 percent. Because of the relatively few patients with previously diagnosed high-risk conditions, assessing possible changes in other risk factors was difficult. However, several risk factors (hypertension, cardiovascular disease, and diabetes) that were noted in hospital stays during the 6 months before surgery were somewhat higher for 1982-83 cholecystectomy patients than for their 1972-73 counterparts.

The only marked change in the practice of prostatectomy over this decade was the increase in procedures performed using the transurethral approach, from 70.4 percent to 83.4 percent (Table 4). Both the age distribution and the proportion of patients with multiple diagnoses changed only slightly.

In Table 5, we present data on the proportion of procedures performed at high-volume hospitals and by surgeons with high-volume experience. Surgery in

[1]Most of the drop in Manitoba cholecystectomy rates occurred from 1972-73 to 1977-78, a period during which ICDA-8 coding was used. Any coding changes could have affected the data only after the April 1, 1979, changeover. ICDA-8 and ICD-9-CM coding is very straightforward for the surgical procedures studied here.

Table 1

Number and age-sex-adjusted rate for 3 common surgical procedures: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure	1972-73	1977-78	1982-83
Hysterectomy			
Number	4,126	3,752	3,247
Annual rate per 1,000 females 25 years of age or over	7.3	6.1	5.1
Cholecystectomy			
Number	6,833	4,632	3,772
Annual rate per 1,000 population 25 years of age or over	6.2	3.8	3.0
Prostatectomy			
Number	2,141	2,258	2,276
Annual rate per 1,000 males 25 years of age or over	3.9	3.9	3.7

NOTES: Procedures involving associated malignancies (noted on the hospital claim for the surgical procedure) are excluded in this and subsequent tables. Only hysterectomies, cholecystectomies, and prostatectomies coded as the primary procedure on the hospital discharge abstract are counted in this and subsequent tables. Details are given in the technical note. Rates have been adjusted using the direct method with the distribution of the combined population (population of all 6 years) as the standard.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 2

Percent of hysterectomies, by selected patient characteristics and type of procedure: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Characteristic	1972-73	1977-78	1982-83
		Percent	
Age			
25-34 years	13.7	16.0	14.9
35-44 years	35.8	34.4	37.0
45-54 years	36.0	31.3	28.6
55 years or over	14.5	18.3	19.6
Multiple diagnoses at time of surgery	87.5	92.5	77.8
Diagnoses of unrelated malignancy or heart disease at time of surgery	.4	.8	.3
Type of procedure			
Vaginal	25.4	24.7	20.1
		Number	
Number of procedures	4,126	3,752	3,247

NOTE: Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 3
Percent of cholecystectomies, by selected patient characteristic and type of procedure: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Characteristic	1972-73	1977-78	1982-83
		Percent	
Age			
25-44 years	37.9	34.9	35.5
45-64 years	44.1	42.4	38.0
65-74 years	12.8	15.4	17.6
75 years or over	5.2	7.2	9.0
Multiple diagnoses at time of surgery	33.4	39.8	44.6
Diagnoses of unrelated malignancy or heart disease at time of surgery	2.3	2.7	1.6
Type of procedure			
Exploration of common bile duct	8.9	9.8	11.6
		Number	
Number of procedures	6,833	4,632	3,772

NOTE: Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 4
Percent of prostatectomies, by selected patient characteristic and type of procedure: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Characteristic	1972-73	1977-78	1982-83
		Percent	
Age			
25-64 years	26.9	24.9	21.3
65-74 years	38.3	40.4	42.3
75-84 years	26.7	26.8	28.3
85 years or over	8.2	8.7	8.0
Multiple diagnoses at time of surgery	67.0	67.5	63.6
Diagnoses of unrelated malignancy or heart disease at time of surgery	8.9	8.9	5.7
Type of procedure			
Transurethral prostatectomy	70.4	74.1	83.4
		Number	
Number of procedures	2,141	2,258	2,276

NOTE: Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Manitoba tends to be more concentrated in high-volume hospitals than surgery in the United States (Roos and Ramsey, 1987; Roos and Danzinger, 1986). However, over the decade, the percentage of hysterectomies performed at high-volume hospitals dropped slightly (from 81.2 percent in 1972-73 to 76.0 percent in 1982-83). The proportion of cholecystectomies in high-volume hospitals remained basically unchanged, and the percentage of prostatectomies performed in high-volume hospitals increased, from 82.6 to 95.8.

Despite the high percentage of procedures done in high-volume hospitals, many hospitals performed 10

Table 5
Percent of 3 common procedures performed at high-volume hospitals and percent performed by surgeons with high-volume experience: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure and characteristic	1972-73	1977-78	1982-83
		Percent	
Hysterectomy			
High-volume hospitals	81.2	78.1	76.0
High-volume surgeons	69.2	68.6	71.1
Cholecystectomy			
High-volume hospitals	76.4	76.5	77.8
High-volume surgeons	74.1	69.7	76.5
Prostatectomy			
High-volume hospitals	82.6	85.5	95.8
High-volume surgeons	82.1	82.4	87.9

NOTES: High-volume hospitals were identified as those performing 200 or more of the indicated procedure over a 2-year period. High-volume surgeons were identified as those performing 40 procedures or more over the 2-year period for hysterectomies or cholecystectomies and 100 or more for prostatectomies. Percentages are based on number of procedures (Table 1). Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

or fewer procedures a year. Thus, although no more than eight hospitals were labeled "high volume" for any of the procedures, 16, 31, and 37 hospitals, respectively, performed hysterectomies, cholecystectomies, and prostatectomies in 1982-83.

The proportion of procedures performed by high-volume surgeons increased slightly over the period (Table 5). The largest change was for prostatectomy, with the percentage done by high-volume surgeons increasing to 87.9 percent from 82.1 percent at the beginning of the decade.

All three procedures showed a marked decline in the number of physicians performing the given operation infrequently. This drop was most dramatic for hysterectomy, with a decline from 135 physicians performing the surgery one to five times during 1972-73 to 48 physicians doing so during 1982-83.

Over the decade, the proportion of surgery done by board-certified specialists increased while that performed by general practitioners decreased (Table 6). In 1972-73, 72.4 percent of hysterectomies were performed by gynecologists and 14.4 percent by general practitioners. However, these percentages had shifted to 81.7 and 8.4 percent, respectively, by 1982-83. Similarly, the proportion of cholecystectomies done by general surgeons increased, and those done by general practitioners decreased. By 1982-83, almost all prostatectomies (98.7 percent) were performed by board-certified urologists.

Surgical outcomes

Postsurgical mortality rates (all deaths occurring in the 90 days following surgery, whether before or after hospital discharge) are presented in Table 7 for each

Table 6

Percent of physicians performing 3 common surgical procedures, by specialty qualifications: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure and specialty qualification	1972-73	1977-78	1982-83
		Percent	
Hysterectomy			
Gynecologist	72.4	78.1	81.7
General surgeon	11.5	10.9	9.9
General practitioner	14.4	10.0	8.4
Other	1.8	1.0	.0
Cholecystectomy			
General surgeon	72.0	82.0	88.8
General practitioner	24.4	15.6	9.1
Other	3.6	2.5	2.2
Prostatectomy			
Urologist	90.6	94.1	98.7
Other	9.4	5.9	1.3

NOTES: Percentages are based on number of procedures (Table 1). Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

cohort. Over the decade, postoperative mortality rates associated with these three common surgical procedures changed relatively little. Hysterectomy mortality rates ranged from 1.5 per 1,000 procedures in 1972-73 to 0.6 per 1,000 procedures in 1982-83. For cholecystectomy, the range was from 6.0 to 8.0;[2] for prostatectomy, the postoperative death rate of 29.9 in 1972-73 declined somewhat, to 24.6 in the early 1980's. The chi-square associated with this decline was not significant at the .05 level.

So few deaths were associated with hysterectomy that generalizing about shifts in mortality rates is difficult. However, both cholecystectomy and prostatectomy are higher risk procedures. As reported in Table 3, the case mix of cholecystectomy changed over the decade to include a larger portion of quite elderly people (from 5.2 percent of surgical cases to 9.0 percent); postoperative mortality rates are much higher in this age group (44.4 deaths per 1,000 procedures in 1982-83 for those 75 years or over versus 0.7 per 1,000 in the age group 25-44). This case-mix shift explains the rise in postoperative mortality associated with cholecystectomy over the decade. The age-specific mortality rates following cholecystectomy changed little in the younger age group; in the oldest group, 75 years or over, mortality declined slightly (from 53.2 in 1972-73 to 44.4 more recently). Further runs including all malignancies (as well as cholecystectomies performed as other than the primary procedure) showed no such decline for the oldest group; deaths per 1,000 cholecystectomies ranged from 63.1 to 68.9 over the decade. Exploration of the common bile duct was associated with a higher postoperative mortality rate in the 1980's (34.2, compared with 14.8 in 1972-73). Differences were even more dramatic when malignancies were included; the postoperative mortality rate for cholecystectomies with exploration of the common bile duct increased from 17.0 deaths per 1,000 in 1972-73 to 51.9 deaths per 1,000 in 1982-83.

Younger prostatectomy patients had a slight (nonsignificant) decline in postoperative mortality. The postoperative mortality rate in those 85 years or over remained high at both the beginning and the end of the decade (108.6 to 109.3 deaths per 1,000 procedures, respectively). Although the percentage of procedures performed transurethrally increased (Table 4), the mortality rate associated with this surgical approach remained essentially unchanged (26.5 in 1972-73 and 23.7 in 1982-83). Mortality associated with open procedures fell from 37.9 postoperative deaths per 1,000 in 1972-73 to 21.1 in 1982-83.

Over the decade, 69 percent of the deaths associated with hysterectomy occurred after discharge from the hospital, as did 39 percent of the deaths following cholecystectomy and 54 percent of those after prostatectomy. This figure has remained relatively constant over the years. In 1972-73, 47 percent of the deaths within 90 days of surgery for these three procedures occurred after the patient had been discharged, compared with 53 percent in 1982-83.

Many hospital readmissions in the period immediately following surgery have been shown to be precipitated by complications of surgical procedures. Thus, 77 percent of the readmissions in the first month after hysterectomy were judged by physician panels to be complications (Roos et al., 1985). Examining such early readmissions helps in estimating whether surgical complications increased or decreased in the period 1972-83.

Readmissions in the 6 weeks immediately following surgery declined slightly for the hysterectomy and prostatectomy cohorts (from 3.6 percent to 3.1 percent readmitted after hysterectomy and from 9.6 percent to 8.2 percent readmitted after prostatectomy). Cholecystectomy patients had the reverse pattern (Table 8). The percentage of patients readmitted within 6 weeks of cholecystectomy increased from 3.2 percent in 1972-73 to 4.0 in 1982-83. This was the only statistically significant change (chi square = 4.37, p = .04). Readmissions in the 43- to 90-day period, a reasonably high proportion of which have been shown to be associated with surgery, showed declines for all three procedures.

These declines in rates of readmission may relate to more general changes in the health care system rather than to an actual decrease in postsurgical complications. Data on hospital readmissions in the period 91-455 days (3 months to 15 months) after surgery are also shown in Table 8. After 90 days, only a small proportion of patients admitted to the hospital

[2] The cholecystectomy data are complicated by a measurement problem. Cholecystectomy data for 1972-73 indicate 41 postoperative deaths and five cases that were missing within 30 days of surgery. If these possible deaths were included, the cholecystectomy postoperative mortality rate in 1972-73 would have been 6.7. However, none of these individuals had common bile duct surgery.

Table 7

Number of deaths within 90 days of surgery for 3 common procedures and rate per 1,000 procedures, by patient characteristic and type of procedure: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure and characteristic	1972-73	1977-78	1982-83	1972-73	1977-78	1982-83
	Number of deaths			Deaths per 1,000 procedures		
Hysterectomy						
Total	6	3	2	1.5	0.8	0.6
Age						
20-34 years	2	0	0	3.5	0.0	0.0
35-44 years	1	0	0	0.7	0.0	0.0
45-54 years	1	2	0	0.7	1.7	0.0
55 years or over	2	1	2	3.4	1.5	3.1
Multiple diagnoses at time of surgery	6	2	2	1.7	0.6	0.8
Type of procedure:						
Abdominal	3	3	0	1.0	1.1	0.0
Vaginal	3	0	2	2.9	0.0	3.1
Cholecystectomy						
Total	41	28	30	6.0	6.0	8.0
Age						
25-44 years	2	1	1	0.8	0.6	0.7
45-64 years	9	4	4	3.0	2.0	2.8
65-74 years	11	8	10	12.6	11.1	15.1
75 years or over	19	15	15	53.2	45.3	44.4
Multiple diagnoses at time of surgery	41	27	28	18.0	14.7	16.6
Type of procedure:						
No exploration	32	22	15	5.1	5.3	4.5
Exploration of common bile duct	9	6	15	14.8	13.3	34.2
Prostatectomy						
Total	64	53	56	29.9	23.5	24.6
Age						
25-64 years	5	4	2	8.7	7.4	4.1
65-74 years	17	13	15	20.8	14.3	15.6
75-84 years	23	20	16	40.3	33.0	24.8
85 years or over	19	16	20	108.6	81.2	109.3
Multiple diagnoses at time of surgery	58	52	46	40.4	34.1	31.8
Type of procedure:						
Transurethral	40	42	45	26.5	25.1	23.7
Open	24	11	8	37.9	18.8	21.1

NOTE: Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 8
Percent of hospital readmissions for any reason in the 15 months following 3 common surgical procedures, by time from procedure to readmission: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure and time to readmission	Year of surgery		
	1972-73	1977-78	1982-83
Hysterectomy		Percent	
1-42 days	3.6	3.4	3.1
43-90 days	2.0	1.3	1.1
91-455 days	12.9	10.8	10.0
Cholecystectomy			
1-42 days	3.2	3.1	4.0
43-90 days	2.6	2.3	2.1
90-455 days	14.5	13.0	12.1
Prostatectomy			
1-42 days	9.6	7.5	8.2
43-90 days	6.8	5.5	4.9
90-455 days	19.9	20.1	20.2

NOTES: Individuals not covered in the provincial health insurance system for at least 15 months following surgery or until death are excluded. The numbers of patients available for analysis in each of the 3 cohorts, beginning with 1972-73, were as follows: hysterectomy—4,048, 3,679, 3,202; cholecystectomy—6,687, 4,565, 3,726; prostatectomy—2,114, 2,237, 2,258. Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 9
Percent of hospital readmissions for adverse surgical outcomes in the 15 months following 3 common surgical procedures, by reason for readmission: Manitoba, Canada, 1972-73 and 1982-83

Procedure and reason for readmission	Year of surgery	
	1972-73	1982-83
	Percent	
Hysterectomy	4.3	3.0
Post-discharge hemorrhage	0.8	0.7
Wound infection, ventral hernia and fistulas	1.0	0.8
Vaginal enterocele, stricture vault prolapse, repair procedure for incontinence	0.5	0.2
Other	2.0	1.3
Cholecystectomy	2.9	2.7
Wound infection, ventral hernia	0.9	1.3
Retained stones, other gallbladder disease	1.1	0.7
Abdominal pain	0.2	0.3
Other	0.7	0.4
Prostatectomy	6.7	5.6
Postdischarge hemorrhage	1.8	1.3
Urethral stricture, contracture of bladder	1.8	1.7
Retention, hematuria	1.4	1.6
Other	1.7	1.0

NOTES: A complete listing of complications and their respective codes is given in Roos et al. (1985). Readmissions are counted in only one category. Individuals not covered in the provincial health insurance system for at least 15 months following surgery or until death are excluded. The numbers of patients available for analysis in each cohort, beginning with 1972-73, were as follows: hysterectomy—4,048, 3,202; cholecystectomy—6,687, 3,726; prostatectomy—2,114, 2,258. Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

are readmitted for complications related to the original surgery (Roos et al., 1985). These later admissions generally result from the development of new health problems or the recurrence of chronic conditions. The data for hysterectomies and cholecystectomies shown in Table 8 suggest that late, probably unrelated hospital admissions have also fallen over the decade.

In Table 9, we report readmission rates in the 15 months following surgery for complications judged by a physician panel to be associated with the prior surgery. Some complications were common across two or more procedures. (Post-discharge hemorrhage was one of the most frequent causes of readmissions for patients following both prostatectomy and hysterectomy; wound infections and ventral hernias were common causes of readmission for hysterectomy and cholecystectomy patients.) Others were clearly specific to the reason surgery had been undertaken in the first place. Overall, the highest rate of readmissions for complications occurred in prostatectomy patients (6.7 percent of the patients being readmitted after surgery performed in 1972-73 and 5.6 percent for 1982-83). Each of the three procedures had a slight decline in the rate of readmissions for adverse outcomes in 1982-83 compared with the earlier years.

Hospitals with adverse outcomes

Another approach to quality assessment is suggested by the growing literature on institutional differences in outcomes (Luft and Hunt, 1986; Wagner, Knaus, and Draper, 1986; Showstack et al., 1987). Both in Manitoba and elsewhere, hospitals and surgeons differ significantly in their postsurgical outcomes (Roos et al., 1986; Wennberg et al., 1987). Although some differences relate to volume and experience, individual hospitals delivering poorer than expected care have also been identified.

In this research, we explored the feasibility of identifying hospitals with possible problems in quality of care using computerized data. The three procedures—hysterectomy, cholecystectomy, and prostatectomy—were studied for surgery performed in 1972-73 and 1982-83. Although several thousand procedures of each type were performed, the number of readmissions and postsurgical deaths was quite low, reducing statistical power (Tables 7-9). As shown later, relationships had to be fairly strong (with adjusted odds ratios less than .70 or greater than 1.50) to be statistically significant.

More specifically, in this section of the article, we address the problems of how to adequately control for comorbidity in comparing outcomes among hospitals and how much information is necessary to efficiently

Table 10
Diagnoses associated with hospital admissions in the 6 months prior to surgery—possible case-mix controls for study of 3 common procedures: Manitoba, Canada, 1982-83

Diagnosis and ICD-9-CM code[1]	Hysterectomy	Cholecystectomy	Prostatectomy
		Number of cases with indicated diagnoses	
All diagnoses	567	908	567
Cancer (140-208, 238)	8	12	46
Cancer of prostate (185)	—	—	7
Cancer of bladder (188)	—	—	4
Cancer other than prostate or bladder (140-184, 186-187, 189-208, 238)	—	—	35
Hypertension (401-405)	21	58	38
Cardiovascular disease[2] (410-412, 413.0, 414, 428, 429.2)	4	59	78
Diabetes (250)	12	24	39
Chronic obstructive pulmonary disease (490-493, 496)	5	24	51

[1] Codes from the *International Classification of Diseases, 9th Revision, Clinical Modification* (Public Health Service and Health Care Financing Administration, 1980) are included in parentheses with each set of diagnoses.
[2] The cardiovascular disease category is that used by Wennberg et al. (1987).

NOTES: For hysterectomy, N = 3,201; for cholecystectomy, N = 3,723; for prostatectomy, N = 2,221. Because of missing values, the numbers of operations are slightly less than those shown in Table 8. Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

compare surgical outcomes across different hospitals.

Controlling for comorbidity involves using variables from the hospital discharge abstracts to adjust for possible differences among hospitals in patient case mix. Hospital claims can be used approximately as well to generate appropriate covariates for studying surgical outcomes as can information from physician visits and from surveys (Mossey and Roos, 1987; Roos et al., 1986). In ongoing work, hospital claims data are being compared with information more laboriously collected in the clinical situation (Roos, to be published). Some of the variables considered as potential case-mix controls in this study are presented in Table 10. The variables were developed from hospitalization data for the 6 months before the indicated surgery (hence the inclusion of various malignancies).

As seen in Table 10, using the presence or absence of a hospital admission (regardless of diagnosis) in the 6 months before surgery provides enough admissions to give a good split on this dichotomous predictor. The specific diagnoses that, on clinical grounds, might be suitable covariates often do not include enough individuals having the specified condition to be statistically significant predictors; combining several diagnoses into one variable may be necessary.

Analyses of admissions in 1982-83

Following work on data from the 1970's (Roos et al., 1986), logistic regression was used to examine the predictors of readmission within 42 days (6 weeks) of hysterectomy, cholecystectomy, and prostatectomy performed in 1982-83. In Tables 11 and 12, we present the logistic regressions for hysterectomy and cholecystectomy. Age was a significant predictor of

Table 11
Results of logistic regression for readmission within 42 days following hysterectomy: Manitoba, Canada, 1982-83

Variable[1]	Beta	Adjusted odds ratio	95-percent confidence interval
Diagnosis of cancer, chronic ischemic heart disease, or congestive heart failure[1] at event (No) Yes	*2.28	9.75	2.64-35.97
Hospital where surgery was performed (High-volume hospitals) Other hospitals	0.52	1.68	1.10-2.56
Age (45 years or over):			
25-34 years	*0.81	2.25	1.31-3.86
35-44 years	0.50	1.66	1.05-2.62

*Statistically significant at the .01 level.
[1] Codes from the *International Classification of Diseases, 9th Revision, Clinical Modification* (Public Health Service and Health Care Financing Administration, 1980) include 140-208, 238, 412, 414, 428, and 429.2.

NOTES: Reference levels for variables are shown in parentheses. All variables included were statistically significant at the .05 level. Individuals not covered in the provincial health insurance system for at least 15 months following surgery or until death are excluded. The number of patients available was 3,202. Rank correlation between predicted probability and response = 0.20. Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Table 12
Results of logistic regression for readmission within 42 days following cholecystectomy: Manitoba, Canada, 1982-83

Variable	Beta	Adjusted odds ratio	95-percent confidence interval
Common bile duct exploration performed at event (No) Yes	0.51	1.67	1.09-2.56
Hospitalization in 6 months prior to surgery (No) Yes	0.52	1.68	1.18-2.38
Age (25-64 years):			
65-74 years	0.47	1.60	1.07-2.40
75 years or over	*0.74	2.10	1.31-3.36
Hospital where surgery was performed (High-volume hospitals)			
Other hospitals	0.45	1.57	1.09-2.28
Multiple diagnoses at event (Yes) No	−0.38	0.69	0.48-0.99

*Statistically significant at .01 level.

NOTES: Reference levels for variables are shown in parentheses. All variables included were statistically significant at the .05 level. Individuals not covered in the provincial health insurance system for at least 15 months following surgery or until death are excluded. The number of patients available was 3,726. Rank correlation between predicted probability and response = 0.32. Excludes procedures involving related malignancies.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

readmission in both cases. For hysterectomy, the younger individuals tended to be readmitted within 42 days after the operation; following cholecystectomy, the older individuals were more likely to be readmitted. Several variables relating to likely patient health status were correlated with readmission following each operation. Having a diagnosis of cancer, chronic ischemic heart disease, or congestive heart failure led to a much greater probability of readmission after hysterectomy. Multiple diagnoses at the time of surgery and hospitalization in the 6 months prior to the operation were statistically significant predictors of readmission following cholecystectomy. As expected, when common bile duct exploration accompanied cholecystectomy, readmission within 42 days after surgery was more likely.

Hospitals designated as "other" (other than six high-volume hospitals for hysterectomy and eight for cholecystectomy) were identified specifically. These 1982-83 findings that patients having surgery in "other" hospitals were more likely to be readmitted in the 42 days after surgery is worth attention. All "other" hospitals were categorized as low volume. Many of the physicians in these hospitals did relatively few operations annually, compared with those in the larger hospitals. Because almost all of these low-volume hospitals are rural, the analyses were replicated using rural residents, who enter both urban and rural hospitals. The direction of bias is toward urban hospitals getting sicker patients (because of the referral process); the results, however, were similar to those reported in Tables 11 and 12.

Pooled analyses

The 1972-73 and 1982-83 data were pooled (and distinguished by a dummy variable) to provide a greater number of cases. For these analyses (not presented in tables here), hospital volume was an important predictor of readmissions within 42 days for both hysterectomy and cholecystectomy. This same volume variable proved statistically significant for predicting readmissions for complications within 15 months of surgery for cholecystectomy but not for hysterectomy. Hospital surgical volume was not a predictor of mortality in the 91 days after either hysterectomy or cholecystectomy. Of eight different analyses for hysterectomy and cholecystectomy, in only one regression was year of surgery (1972-73 versus 1982-83) a statistically significant predictor. In this case, the odds of a 1982-83 cholecystectomy patient being readmitted with complications within 15 months were 83 percent of those for a 1972-73 patient.

The analyses of prostatectomy presented somewhat different problems. As seen in Table 5, prostatectomies were concentrated in high-volume hospitals and performed by high-volume surgeons, with very few operations in low-volume hospitals and by low-volume practitioners. However, despite the fact that only 10 percent of the prostatectomy operations occurred in low-volume hospitals, the variable was significant in predicting readmissions within 15 months of surgery. Other predictors of readmission and survival after prostatectomy were related either to the physical condition of the patient or to the type of surgery.

Discussion

These findings suggest practical ways to compare surgical outcomes across time. Administrative data banks such as those now available in the United States for the Medicare population are well suited for the quality-of-care analyses reported here. Postoperative deaths can be tracked whether they occur before or after discharge from a hospital (Lubitz, Riley, and Newton, 1985) and hospital readmissions within specific time periods can be assessed (Anderson and Steinberg, 1984). If diagnoses and operation codes from the International Classification of Diseases are available, the algorithms developed in Manitoba for tracking postsurgical complications during the 2 years after surgery can be applied. (SAS programs are available from the authors.) Such studies are important for monitoring changes in quality of care, given the concern that prospective payment systems in the United States may adversely affect the quality of care available to the elderly.

However, before drawing firm conclusions about a relationship between changes in postoperative readmission rates and improvements or declines in quality of care, system-wide changes in hospital admission patterns must be considered. For example, in Manitoba, a 20-percent increase in patient days available in public general hospitals from 1971 to 1981-82 was entirely consumed by patients staying 60 days or longer, but postsurgical readmissions are almost always for short stays (Roch, Evans, and Pascoe, 1985). Over the same period, the acute bed days available to short-stay Manitoba patients actually fell 12.6 percent. Thus, any decline in postsurgical admission rates must be assessed in light of the general decrease in the availability of acute care beds. Much of the decline in readmission rates found in our analyses probably results from this overall tightening in the supply of acute beds. Such an explanation is supported by our finding that readmissions in the period from 3 to 15 months after surgery (only a small fraction of which represent complications) also declined over the decade under study.

In some researchers' opinions, drops in the numbers of hysterectomies and cholecystectomies per se probably indicate improved care (Wennberg, Bunker, and Barnes, 1980; Roos, 1984). Such decreases occurred with minimal changes in the amount of regional variation from 1972-73 to 1982-83; thus, possible access problems were not created by a disproportionate drop in any one region. On the other hand, few dramatic changes in postsurgical mortality, readmissions, or complications over the past decade can be demonstrated for the three procedures reviewed in this article. The differences that do occur appear to be most plausibly explained, not by changes in quality of care, but by changes in case mix (for cholecystectomy) and in acute bed availability (for readmissions after surgery). In the case of cholecystectomy with exploration of the common bile duct, further analysis of trends in mortality to explain the rise over the decade might be fruitful.

Other analyses of postsurgical problems might deal with hospital outpatient visits and physician visits. Such work is possible with both Manitoba and Medicare data. Research using physician visits, however, involves access to additional, larger data sets and would tend to slow down analyses directed toward monitoring and prompt feedback of results to hospitals. Because inhospital mortality can be measured from data on hospital discharge abstracts, ongoing research is directed toward assessing the extent to which this simpler measure can be substituted for mortality at specific time intervals (such as within 90 days after surgery). Use of such an inhospital mortality measure bypasses the need to check deaths against registry data, adding to the speed with which monitoring and feedback can be carried out.

The Manitoba situation provides a classic demonstration of "flat of the curve" medicine (Bunker, 1978; Neuhauser, 1977). In the early 1970's, the organization and delivery of care for these three procedures were of such a quality that improving surgical outcomes proved difficult. Thus, as far as we can demonstrate in Manitoba, growth in both centralization of surgery and the proportion of procedures performed by high-volume specialists has only slightly reduced adverse outcomes following hysterectomy, cholecystectomy, and prostatectomy.

These findings and others have shown that it is possible to identify institutions with outcomes that should be carefully reviewed. Careful monitoring of and feedback to institutions with poorer than expected outcomes seem likely to have a much greater impact on quality than the incremental system-wide increases in expenditures that are the norm. Given reasonably high overall quality, achieving even small improvements is difficult. An emphasis on monitoring and feedback focuses efforts on the hospitals where improvement is most feasible.

Technical note

The ICDA-8 and ICD-9-CM codes used in this article are shown in Figure 1. Details on case selection are shown in Table 13.

Figure 1
Eighth Revision International Classification of Diseases, Adapted for Use in the United States, ICDA-8, and International Classification of Diseases, 9th Revision, Clinical Modification, ICD-9-CM, codes

Hysterectomy:

Exclude cases if any of first three diagnoses were malignancies of digestive organs, uterus, or lymphoid tissue or complications of pregnancy—150-159, 180-184, 202, 630-677 (ICDA-8); 150-159, 179-184, 202, 630-674 (ICD-9-CM).

Include only if primary procedure was hysterectomy—69.2 or 69.4 (ICDA-8); 68.4 or 68.5 (ICD-9-CM).

Cholecystectomy:

Exclude cases if any of first three diagnoses was malignancy of gallbladder, pancreas, peritoneum, or unspecified digestive organs—156-159 (ICDA-8 and ICD-9-CM).

If any of operation codes was anastomosis or repair and plastic operations on bile ducts, cholecystotomy, or anastomosis of gallbladder—43.1-43.4, 43.6 (ICDA-8); 51.0, 51.3, 51.6, 51.7 (ICD-9-CM).

Include only if primary procedure was cholecystectomy—43.5 (ICDA-8); 51.22 (ICD-9-CM).

If primary diagnosis was cholelithiasis, cholecystitis, cholangitis, disease of pancreas, or symptoms referable to abdomen and lower gastrointestinal tract—574, 575, 577, 785 (ICDA-8); 574.0-575.1, 576, 577 (ICD-9-CM).

Prostatectomy:

Exclude cases if any of first three diagnoses was malignancy of prostate or bladder—185 or 188 (ICDA-8 and ICD-9-CM).

Include only if primary procedure was prostatectomy—58.1-58.3 (ICDA-8); 60.2-60.6 (ICD-9-CM).

SOURCE: (National Center for Health Statistics, 1967; Public Health Service and Health Care Financing Administration, 1980).

Table 13
Exclusions from the analyses of three common surgical procedures, by time period: Manitoba, Canada, 1972-73, 1977-78, and 1982-83

Procedure and time period	All cases	Number after exclusions based on malignancy diagnosis	Number after additional exclusions based on primary procedure and diagnosis	Final number
Hysterectomy				
1972-73	4,561	4,271	4,245	4,126
1977-78	4,253	3,888	3,872	3,752
1982-83	3,777	3,443	3,362	3,247
Cholecystectomy				
1972-73	7,964	7,956	7,641	6,833
1977-78	5,112	5,109	4,936	4,632
1982-83	4,389	4,385	4,145	3,772
Prostatectomy				
1972-73	2,785	2,321	2,187	2,141
1977-78	3,040	2,463	2,318	2,258
1982-83	3,143	2,524	2,328	2,276

NOTE: Cases were also excluded if patients were under 25 years of age, if they were operated on outside Manitoba, or if they were Treaty Status Indians, a group whose coverage in the claims system may be incomplete.

SOURCE: Government of Manitoba: Data from the Manitoba Health Services Commission.

Acknowledgments

Comments on an earlier draft by Arnold M. Epstein and anonymous reviewers are appreciated. The assistance of Debbie Doan, Bogdan Bogdanovic, and Andre Wajda is acknowledged with thanks.

References

Anderson, G. F., and Steinberg, E. P.: Hospital readmissions in the Medicare population. *New England Journal of Medicine* 311(21):1349-1353, 1984.

Bunker, J. P.: Surgical manpower, use of surgical services, and health status. *Southern Medical Journal* 71(3):230-232, 1978.

Chilton, C. P., Morgan, R. J., England, H. R., et al.: A critical evaluation of the results of transurethral resection of the prostate. *British Journal of Urology* 50(7):542-546, 1978.

Fink, A., ed.: *Appropriateness of Indications for and a Literature Review of Selected Medical and Surgical Procedures: Cholecystectomy.* Rand No. R-3204/3. Santa Monica, Calif. The Rand Corporation, 1986.

Henry, M. L., and Carey, L. C.: Complications of cholecystectomy. *Surgical Clinics of North America* 63(6):1191-1204, 1983.

Lubitz, J., Riley, G., and Newton, M.: Outcomes of surgery among the Medicare aged: Mortality after surgery. *Health Care Financing Review.* Vol. 6, No. 4. HCFA Pub. No. 03205. Office of Research and Demonstrations, Health Care Financing Administration. Washington. U.S. Government Printing Office, Summer 1985.

Luft, H. S., and Hunt, S. S.: Evaluating individual hospital quality through outcome statistics. *Journal of the American Medical Association* 255(20):2780-2784, 1986.

Luft, H. S., Bunker, J. P., and Enthoven, A. C.: Should operations be regionalized? The empirical relation between surgical volume and mortality. *New England Journal of Medicine* 301(25):1364-1369, 1979.

Mindell, W. R., Vayda, E., and Cardillo, B.: Ten year trends in Canada for selected operations. *Canadian Medical Association Journal* 127(1):23-27, 1982.

Moore, F. D.: Surgical manpower: Summary and conclusions. In *Surgery in the United States: A Summary Report of the Study on Surgical Services for the United States.* Baltimore. American College of Surgeons, American Surgical Association.

Mossey, J. M., and Roos, L. L.: Using insurance claims to measure health status: The illness scale. *Journal of Chronic Diseases* 40(Supplement):41S-50S, 1987.

National Center for Health Statistics: *Eighth Revision International Classification of Diseases, Adapted for Use in the United States.* PHS Pub. No. 1693. Public Health Service. Washington. U.S. Government Printing Office, 1967.

Neuhauser, D.: Cost-effective clinical decision-making: Implications for the delivery of health services. In Bunker, J. P., Barnes, B. A., and Mosteller, F., eds. *Costs, Risks, and Benefits of Surgery.* New York. Oxford University Press, 1977.

Public Health Service and Health Care Financing Administration: *International Classification of Diseases, 9th Revision, Clinical Modification.* DHHS Pub. No. (PHS) 80-1260. Public Health Service. Washington. U.S. Government Printing Office, Sept. 1980.

Riley, G., and Lubitz, J.: Outcomes of surgery in the Medicare aged population: Surgical volume and mortality. *Health Care Financing Review.* Vol. 7, No. 1. HCFA Pub. No. 03206. Office of Research and Demonstrations, Health Care Financing Administration. Washington. U.S. Government Printing Office, Fall 1985.

Roch, D. J., Evans, R. G., and Pascoe, D. W.: *Manitoba and Medicare—1971 to the Present.* Department of Research, Manitoba Health. Winnipeg, Manitoba, 1985.

Roos, L. L., Cageorge, S. M., Austen, E., and Lohr, K. N.: Using computers to identify complications after surgery. *American Journal of Public Health* 75(11):1288-1295, 1985.

Roos, L. L., Cageorge, S. M., Roos, N. P., and Danzinger, R. G.: Centralization, certification, and monitoring: Readmissions and complications after surgery. *Medical Care* 24(11):1044-1066, 1986.

Roos, L. L., Nicol, J. P., and Cageorge, S. M.: Using administrative data for longitudinal research: Comparisons with primary data collection. *Journal of Chronic Diseases* 40(1):41-49, 1987.

Roos, L. L., Roos, N. P., Cageorge, S. M., and Nicol, J. P.: How good are the data? Reliability of one health care data bank. *Medical Care* 20(3):266-276, 1982.

Roos, N. P.: Hysterectomies in one Canadian province. A new look at risks and benefits. *American Journal of Public Health* 74(1):39-46, 1984.

Roos, N. P.: Using administrative data to study outcomes; developing control groups and adjusting for case severity. *Social Science and Medicine.* To be published.

Roos, N. P., and Danzinger, R.: Assessing surgical risks in a population: Patient histories before and after cholecystectomy. *Social Science and Medicine* 22(5):571-578, 1986.

Roos, N. P., and Ramsey, E.: A population-based study of prostatectomy: Long term outcomes associated with differing surgical approaches. *Journal of Urology* 137:1184-1188, 1987.

Rutkow, I. M.: Surgical operations and manpower in the United States: A critical review. In Finkel, M. L., ed. *The Delivery of Surgical Care in the United States: A Policy Perspective.* Baltimore. Johns Hopkins University Press. To be published.

Rutkow, I. M., and Zuidema, G. D.: Surgical rates in the United States: 1966-1978. *Surgery* 89:151-162, 1981.

Showstack, J. A., Rosenfeld, R. E., Garnick, D. W., et al.: Association of volume with outcome of coronary artery bypass graft surgery: Scheduled versus nonscheduled operations. *Journal of the American Medical Association* 257(6):785-789, 1987.

Wagner, D. P., Knaus, W. A., and Draper, E. A.: The case for adjusting hospital rates for severity of illness. *Health Affairs* 5(2):148-153, 1986.

Wajda, A., and Roos, L. L.: Simplifying record linkage: Software and strategy. *Computers in Biology and Medicine.* To be published.

Wennberg, J. E., Bunker, J. P., and Barnes, B.: The need for assessing the outcome of common medical practices. *Annual Review of Public Health* 1:277-295, 1980.

Wennberg, J. E., Roos, N. P., Sola, L., et al.: Use of claims data systems to evaluate health care outcomes: Mortality and reoperation following prostatectomy. *Journal of the American Medical Association* 257(7):933-936, 1987.