Has Misdiagnosis of Appendicitis Decreased Over Time?

A Population-Based Analysis

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Context Misdiagnosis of presumed appendicitis is an adverse outcome that leads to unnecessary surgery. Computed tomography, ultrasonography, and laparoscopy have been suggested for use in patients with equivocal signs of appendicitis to decrease unnecessary surgery.

Objective To determine if frequency of misdiagnosis preceding appendectomy has decreased with increased availability of computed tomography, ultrasonography, and laparoscopy.

Design, Setting, and Patients Retrospective, population-based cohort study of data from a Washington State hospital discharge database for 85 790 residents assigned *International Classification of Diseases, Ninth Revision* procedure codes for appendectomy, and United States Census Bureau data for 1987-1998.

Main Outcome Measure Population-based age- and sex-standardized incidence of appendectomy with acute appendicitis (perforated or not) or with a normal appendix.

Results Among 63 707 nonincidental appendectomy patients, 84.5% had appendicitis (25.8% with perforation) and 15.5% had no associated diagnosis of appendicitis. After adjusting for age and sex, the population-based incidence of unnecessary appendectomy and of appendicitis with perforation did not change significantly over time. Among women of reproductive age, the population-based incidence of misdiagnosis increased 1% per year ($P = .005$). The incidence of misdiagnosis increased 8% yearly in patients older than 65 years ($P < .001$) but did not change significantly in children younger than 5 years ($P = .17$). The proportion of patients undergoing laparoscopic appendectomy who were misdiagnosed was significantly higher than that of open appendectomy patients (19.6% vs 15.5%; $P < .001$).

Conclusion Contrary to expectation, the frequency of misdiagnosis leading to unnecessary appendectomy has not changed with the introduction of computed tomography, ultrasonography, and laparoscopy, nor has the frequency of perforation decreased. These data suggest that on a population level, diagnosis of appendicitis has not improved with the availability of advanced diagnostic testing.

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Appendectomy is one of the most frequently performed surgical procedures in the United States and the most common surgical emergency of the abdomen. Despite a lifetime cumulative incidence of nearly 7%,[1] diagnosis of appendicitis remains a challenge. The risk of 2 primary adverse outcomes must be balanced in management of presumed appendicitis: perforation, often occurring in the prehospital setting,[2] and misdiagnosis, resulting in removal of a normal appendix. Although reduction of the frequency of appendiceal perforation has received much scrutiny, the factors leading to misdiagnosis are less understood.

To reduce the incidence of perforation, the surgical community traditionally accepts that approximately 15% of appendectomies overall and 20% in women will yield a noninflamed appendix.[3,4] The rate of misdiagnosis in certain populations of patients may be as high as 40%.[2,5-7] This relatively high rate of unnecessary appendectomy is being challenged in some quarters as an outdated standard, given the dramatic expansion of diagnostic testing options for appendicitis during the last decade.[8] Indeed, many investigators have demonstrated that in research environments, advanced diagnostic testing using computed tomography (CT), ultrasonography (US), and laparoscopy decreases the frequency of misdiagnosis.[9-14] These diagnostic tests are often targeted toward populations deemed at increased risk for misdiagnosis: children, the elderly, and women of reproductive age.

The purpose of this study was to evaluate changes in the frequency of

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misdiagnosis among patients undergoing appendectomy during a period coincident with the growing availability of CT, US, and laparoscopy. The frequency of misdiagnosis was measured in 2 ways: as a percentage of procedures performed during a given period and as a population-based incidence rate. Reported rates of misdiagnosis classically have been based on the total number of appendectomies performed in a single institution over a fixed period; however, population-based rates account more closely for the true population at risk for appendectomy. We hypothesized that misdiagnosis has decreased since the introduction of advanced diagnostic techniques in the late 1980s. Furthermore, we hypothesized that the greatest decreases in misdiagnosis rate would be identified in populations at increased risk for misdiagnosis because they are more likely to undergo these tests.

METHODS

Study Design

A retrospective cohort study was conducted, using a statewide, population-based hospital discharge database.

Setting

Data were obtained from the Washington State Comprehensive Hospital Abstract Reporting System (CHARS) database. This data set is derived from all public and private hospitals in Washington State (Veterans Affairs and US military hospitals excluded) and includes nearly all of the population of patients undergoing appendectomy in the state of Washington during the study period. The data set contains demographic variables, admission and discharge administrative details, payer status, *International Classification of Diseases, Ninth Revision* (*ICD-9*) procedure and diagnostic codes, and coded hospital identifiers. United States Census Bureau data for total and age- and sex-specific yearly state population estimates were used for population-based analyses. Error due to inclusion of patients in the denominator who had prior appendectomy was assumed to be stable over time. Error due to missing Veterans Affairs and military hospital patients was recognized but represented approximately 0.63% of total statewide cases.

This study was exempted from human subjects review by agreement of the University of Washington Human Subject Review Committee and the Washington State Department of Health. The data set includes only anonymous data and is considered to be within the public domain.

Subjects

All CHARS reports from 1987 through 1998 were searched for *ICD-9* procedure codes pertaining to appendectomy (BOX). This group was then evaluated based on associated *ICD-9* diagnostic codes that described appendiceal pathologic findings and other relevant variables. The total number of appendectomies (incidental and nonincidental) performed were recorded by year.

Variable Definitions

A case of appendicitis was defined as any patient undergoing nonincidental appendectomy with an associated diagnostic code of appendicitis or related appendiceal pathologic finding. A case of misdiagnosis was defined as any patient undergoing nonincidental appendectomy without an associated diagnostic code of appendicitis or related appendiceal pathologic finding. Perforation was defined in a similar fashion, using appropriate *ICD-9* codes (Box).

Analysis

We calculated yearly procedure-based percentages of all appendectomies (incidental and nonincidental) for the entire cohort and for women only, using the total number of procedures as the denominator. In the nonincidental appendectomy group, frequencies of misdiagnosis, appendicitis, and perforation were computed, using the number of nonincidental appendectomies as the denominator. Misdiagnosis frequency was also computed for 3 subpopulations considered at increased risk for misdiagnosis: children younger than 5 years, patients older than 65 years, and women of reproductive age (15-45 years).

Box. *International Classification of Diseases, Ninth Revision* Procedure and Diagnostic Codes

Nonincidental Appendectomy

47	Operations on appendix, excludes incidental
47.0	Appendectomy, excludes incidental
47.01	Laparoscopic appendectomy
47.09	Other appendectomy

Incidental Appendectomy

47.1	Incidental appendectomy
47.11	Laparoscopic incidental appendectomy
47.19	Other incidental appendectomy

Appendicitis

540	Acute appendicitis
5400	With perforation, peritonitis, rupture*
5401	Abscess with generalized peritonitis*
5409	Without mention of perforation, peritonitis, rupture
541	Appendicitis unqualified
542	Other appendicitis

*These codes are used to define patients with perforation or rupture.

Because population-based rates are sensitive to changes in the underlying population at risk for each of these outcomes, yearly population-based rates were calculated for all appendectomies (incidental and nonincidental). Population-based rates of misdiagnosis, appendicitis, and rupture were calculated for the entire nonincidental cohort and for women. Age- and sex-specific population values were used as appropriate. All data were standardized for sex and age using the direct method, with the 1990 population of Washington State as the reference population. All population-based rates are reported as rate per 10 000 person-years. Patients undergoing laparoscopic appendectomy were considered in a separate analysis as well to compare the overall frequency of use and misdiagnosis associated with laparoscopic appendectomy in different subpopulations.

Poisson regression was used to test for a significant increase or decrease over time in the population-adjusted rates of appendectomy, incidental appendectomy, appendicitis, misdiagnosis, and perforation/rupture. The Poisson regression model was used to adjust for the sex and age of the patient. A test for trend (ie, the *P* value for whether the coefficient for calendar year was significantly different from 0) was applied to evaluate significant changes over time in the procedure-based rates of all appendectomies and incidental appendectomies and frequencies of appendicitis, misdiagnosis, and perforation. Statistical analysis was performed using STATA statistical analysis software, version 7 (STATA Corp, College Station, Tex).

RESULTS

During the 12-year study period, 85 790 patients (mean [SD] age, 32.1 [18.6] years; 54.4% female) underwent appendectomy (22.1% incidental). When considered simply as a percentage of all appendectomies performed yearly and analyzed for trend, incidental appendectomy decreased significantly by year, with a corresponding increase in nonincidental appendectomy ($P<.001$). During the study period, 9880 nonincidental appendectomies were performed without an associated diagnosis of appendicitis, representing 15.5% of all nonincidental appendectomies. The average rate of perforation was 25.8%. The percentage of misdiagnoses was greater among women than men (22.8% vs 9.2%, respectively; $P<.001$). Patients with misdiagnoses were slightly older compared with those with appropriate diagnoses (mean, 30.5 vs 28.6 years, respectively; $P<.001$). Among patients undergoing nonincidental appendectomy (n = 63 707), the percentage of misdiagnoses remained stable over time ($P = .06$), as did the percentage with perforated and nonperforated appendicitis ($P = .08$)(TABLE 1).

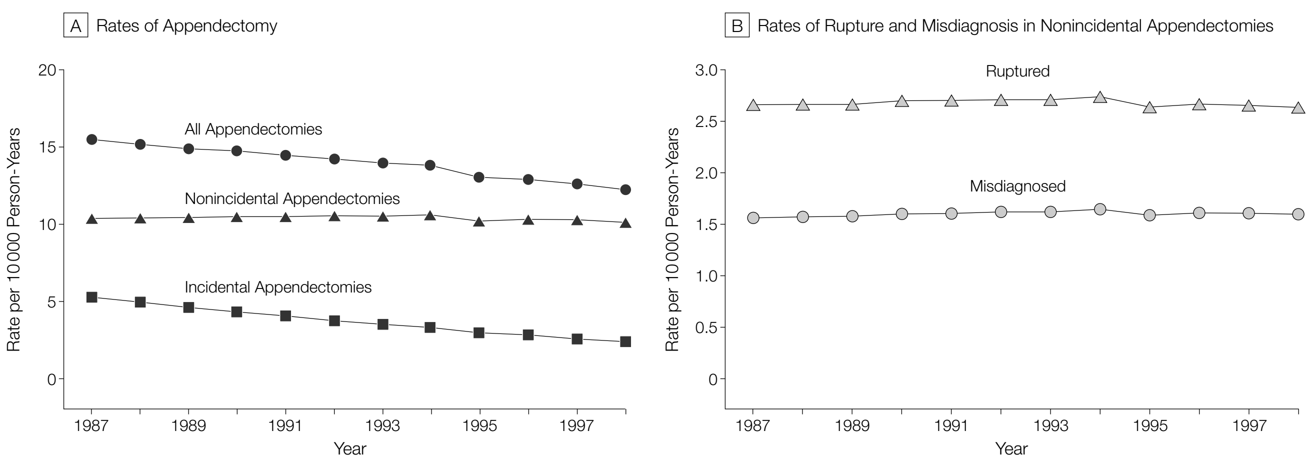
Between 1987 and 1998, there was a 20.3% increase in the state's

Table 1. Appendectomy and Percentage Misdiagnosed and Perforated in Washington State

Year	No. of Nonincidental Appendectomies	Procedures, %* Acute Appendicitis: Nonperforated	Procedures, %* Acute Appendicitis: Perforated	Procedures, %* Misdiagnosis
1987	4754	58.9	25.9	15.2
1988	4973	59.9	25.4	14.7
1989	4863	58.1	26.1	15.8
1990	5101	58.5	25.8	15.7
1991	4959	59.0	25.7	15.3
1992	5428	60.9	24.8	14.3
1993	5381	59.4	25.3	15.3
1994	5701	58.1	25.7	16.2
1995	5515	58.7	25.6	15.7
1996	5680	58.5	25.5	16.0
1997	5724	57.4	26.5	16.1
1998	5628	56.8	27.6	15.6
Average		58.6	25.8	15.5
Total	**63 707**			

*Test for trend indicated no significant trend over time.

Figure. Population-Adjusted Rates of Total, Incidental, and Nonincidental Appendectomy and Misdiagnosis and Rupture in Nonincidental Appendectomy



A, In Washington State, the population-based rate of nonincidental appendectomy remained stable over time, with a decrease in the rate of all appendectomies related to a 7.3% yearly decrease in the rate of incidental appendectomy. B, Among patients undergoing nonincidental appendectomy, the population-adjusted rates of misdiagnosis and perforation remained unchanged from 1987 through 1998.

population. Age- and sex-standardized population-based incidence trends are displayed in the FIGURE. The overall rate of appendectomy per 10000 person-years decreased yearly by 3.1% ($P<.001$). Incidental appendectomy decreased 7.3% yearly, from 5.52 per 10000 person-years in 1987 to 2.45 per 10000 person-years in 1998 ($P<.001$). There was essentially no change in the rate of nonincidental appendectomy per 10000 person-years ($P = .07$). Regression analysis indicates a small decrease (−1.5%) in the yearly rate of appendicitis per 10000 person-years ($P<.001$), but stable rates of misdiagnosis ($P=.27$) and perforation ($P=.51$) over time.

Among women, the decreasing rate of total appendectomies manifested as a significant trend toward fewer incidental appendectomies over time ($P<.001$). The frequency of misdiagnosis among women remained stable over time at an overall rate of 23.2% ($P=.52$). Similar findings were also noted in the sex-specific population-based rates. There was no significant change in the population incidence of nonincidental appendectomy, overall appendicitis, or rate of misdiagnosis in women. Among other subpopulations at risk for misdiagnosis, the population incidence of misdiagnosis actually increased 1% yearly in women of reproductive age ($P=.005$) and increased 8% per year in patients older than 65 years ($P<.001$) (TABLE 2). Misdiagnosis rates did not change significantly in children younger than 5 years ($P=.17$).

Performance of laparoscopic appendectomy, first coded for in 1996, has rapidly increased over time. Laparoscopic appendectomy was performed in 2.8% of all patients in 1996 and in 15.0% of patients in 1998. Laparoscopic appendectomy was performed more often in certain groups of patients. For example, during the 3 years that it was recorded, laparoscopic appendectomy was performed in 13.8% of women and in 17.3% of women of reproductive age. The procedure-based frequency of misdiagnosis among

Table 2. Rates of Appendicitis and Misdiagnosis in High-Risk Groups

Year	No. of Nonincidental Appendectomies	Procedures, %: Acute Appendicitis: Nonperforated	Procedures, %: Acute Appendicitis: Perforated	Procedures, %: Misdiagnosis	Incidence of Misdiagnosis, Misdiagnosed Cases per 10000 Person-Years
Women of Reproductive Age (15-45 y)					
1987	1191	56.2	17.3	26.5	2.89
1988	1264	58.8	16.1	25.2	2.86
1989	1257	56.4	15.2	28.4	3.16
1990	1261	55.7	15.7	28.6	3.13
1991	1251	59.2	15.8	25.0	2.72
1992	1357	60.6	15.8	23.6	2.71
1993	1368	59.6	16.2	24.2	2.77
1994	1462	58.2	15.0	26.7	3.22
1995	1313	57.3	16.7	26.1	2.97
1996	1356	58.8	15.2	26.5	3.06
1997	1447	58.5	15.6	28.7	3.18
1998	1344	56.6	18.4	27.3	2.81
Average		58.0	16.1	26.4	2.96
Change per year, %*					+1
Children (Aged <5 y)					
1987	89	13.5	47.2	39.3	1.01
1988	93	24.7	48.4	26.9	0.71
1989	78	32.1	46.2	21.8	0.47
1990	86	31.4	44.2	24.4	0.55
1991	74	31.1	51.4	17.6	0.34
1992	95	28.4	46.3	25.3	0.61
1993	83	39.8	34.9	25.3	0.53
1994	84	27.4	47.6	15.0	0.54
1995	81	32.1	43.2	24.7	0.52
1996	92	25.0	45.7	29.4	0.70
1997	79	34.2	36.7	30.0	0.60
1998	91	34.1	46.2	20.6	0.46
Average		29.3	44.9	26.0	0.59
Change per year, %†					−2
Older Patients (Aged >65 y)					
1987	243	30.0	55.6	14.4	0.66
1988	265	31.3	57.4	11.3	0.55
1989	258	34.5	50.0	15.5	0.66
1990	239	30.5	57.3	12.1	0.50
1991	241	33.6	50.6	15.7	0.65
1992	269	33.5	49.4	17.1	0.77
1993	253	29.2	50.6	20.1	0.84
1994	307	29.6	49.2	21.1	1.05
1995	278	29.5	48.6	21.9	0.97
1996	339	31.9	49.0	19.1	1.01
1997	342	31.6	50.9	18.3	0.93
1998	341	31.1	42.5	27.7	1.38
Average	3375	31.3	50.6	17.9	0.83
Change per year, %‡					+8

*$P = .005$.
†$P = .17$.
‡$P<.001$.

Table 3. Use and Accuracy of Nonincidental Laparoscopic vs Open Appendectomy

	Misdiagnosis, No./Total Nonincidental (%)					
	All Patients		All Women		Women of Reproductive Age (15-45 y)	
	Laparoscopic	Open	Laparoscopic	Open	Laparoscopic	Open
1996	27/159 (16.9)	883/5521 (15.9)	18/95 (19.0)	576/2497 (23.1)	13/64 (20.3)	340/1292 (26.3)
1997	161/847 (19.0)	758/4877 (15.5)	123/526 (23.4)	494/2181 (22.7)	94/334 (28.1)	281/1113 (25.3)
1998	175/844 (20.7)	706/4784 (14.8)	136/512 (26.6)	472/2151 (21.9)	101/318 (31.8)	235/1026 (22.9)
Total, %	19.6	15.5*	24.4	22.5†	29.1	24.9‡

*$P<.001$.
†$P=.17$.
‡$P=.02$.

patients undergoing laparoscopic appendectomy was higher than that of patients undergoing open appendectomy during the same period (19.6% vs 15.5%, respectively; $P<.001$) (TABLE 3). For all women, the overall frequency of misdiagnosis with laparoscopic appendectomy from 1996 to 1998 was similar to the open appendectomy misdiagnosis rate during the same period (24.4% vs 22.5%, respectively; $P=.17$). Among women of reproductive age, laparoscopic appendectomy was associated with a higher rate of misdiagnosis (29.1% vs 24.9%, respectively; $P=.02$).

COMMENT

The availability of CT, US, and laparoscopy to aid in diagnosis of appendicitis has increased dramatically over the last decade. Controlled clinical trials have suggested that this technology improves diagnostic accuracy.[9-14] We evaluated the 85790 patients in Washington State who underwent appendectomy in 1987-1998, a period concurrent with the increasing availability of this technology. Contrary to expectation, we found that both procedure-based and population-based frequencies of misdiagnosis remained stable over time (15.5% and 1.56 per 10000 person-years, respectively). Likewise, age- and sex-adjusted incidences of perforation remained stable over time (25.8% and 2.71 per 10000 person-years, respectively). Among subpopulations considered at increased risk, the incidence of misdiagnosis actually increased among women of reproductive age and patients older than 65 years. A decrease in the overall rate of appendectomy was also identified but was related to a significant decrease in the rate of incidental appendectomy.

In their landmark 1990 article, Addiss et al[1] first described the method we used to define misdiagnosis and appendicitis within a large administrative data set. These investigators evaluated population trends in appendectomy and appendicitis in 1970-1984 (n=16547). The data source for this work, the National Hospital Discharge Summary, incorporated a 0.5% sample of all patients hospitalized yearly in the United States. While this previous study was based on national survey data, our study was based on data from all Washington State hospital discharge summaries during the years of interest. Both studies defined misdiagnosis as the absence of a diagnosis of acute appendicitis. Both studies are limited by the absence of pathologically confirmed diagnosis and the potential that administrative data are subject to reporting or interpretation errors by personnel who abstract chart data. However, the rate of this type of error may be assumed to be stable over time, allowing for reliable comparison between years.

Most studies of appendicitis use the number of appendectomies performed, often in a single institution, as the denominator for their calculations. Evaluation of population-based data, however, allows for analysis of trends in the true incidence of the process of interest while accounting for changes in the population at risk. Addiss et al,[1] for example, used a population-based technique and found a declining rate of incidental appendectomy between 1979 (year of first incidental coding) and 1984, coincident with a gradually decreasing rate of appendicitis. These researchers found an overall procedure-based rate of misdiagnosis of 14.7% (8.8% in men and 21.4% in women) and that diagnostic accuracy had improved over time, from 74% to 83% in women and from 86% to 92% in men. However, the authors did not calculate a population-based rate of misdiagnosis. This earlier cohort may be considered a historical control for studying the impact of available technology on the diagnosis of appendicitis. In the 1987-1998 Washington State cohort, CT, US, and laparoscopy were widely available to assist in diagnosis of appendicitis (albeit at variable rates), yet we found no improvement in the procedure-based misdiagnosis rate (15.5%) compared with that found in previous work (14.7%).[1]

Our data do not support the hypothesis that the rate of misdiagnosis has improved with the widespread availability of CT, US, and laparoscopy. While state licensing data demonstrate the increasing availability of CT during the study period, this study was limited by our inability to determine the rates of CT and US use with this database. Despite published reports that advocate increased use of advanced diagnostic testing,[9-14] and the informal impression that such testing has increased dramatically, we were unable to identify any direct population-level evidence of increasing CT use in diagnosis of appendicitis. Furthermore, other interventions were advocated during this period to improve diagnosis and management of appendicitis. These included clinical pathways,[15] increased senior surgeon involvement in diagnosis,[16] and better data management tools.[17] We were also unable to determine the extent to which these available interventions were used on a population level. As a result, several explanations for our findings may be proposed. Computed tomography and US may not be performed frequently enough or in the appropriate subpopulations to affect the rate of misdiagnosis. Alternatively, diagnostic tests may be less accurate in a typical clinical environment than in the research setting.[10,18,19] Conversely, these tests may be accurate and performed routinely but may be overruled or not reported rapidly enough to influence decision making. Indeterminate readings and delayed interpretation clearly reduce the potential benefit of such tests. A more clinically detailed data set containing reliable radiological and histological data will be required to clarify this relationship.

Some authors maintain that laparoscopy can decrease the rate of diagnostic error in patients with presumed appendicitis by identifying alternative pathologic findings.[20] After inserting a laparoscope into the abdomen, the surgeon can directly observe the appendix to determine if inflammation is present. This study suggests that the development of laparoscopic appendectomy has not improved diagnostic accuracy in patients with presumed appendicitis. In part, this may be explained by selection bias; patients undergoing laparoscopic appendectomy may be at higher risk for misdiagnosis. However, in our study, even among women of reproductive age, the rate of misdiagnosis was not lower in those undergoing laparoscopic appendectomy. Many surgeons remove a noninflamed appendix when performing laparoscopy, even in the presence of other pathologic findings. For some, acknowledging that the gross appearance of the appendix corresponds poorly to the histological changes of appendicitis,[21] this practice may not be classified as an incidental appendectomy. There is little consensus regarding the appropriate laparoscopic management of the normal-appearing appendix. In 1 survey, the surgeon's assessment of acute inflammation was correct in 120 of 132 cases, a positive predictive value of 91%.[21] Conversely, when surgeons assessed the appendix as being noninflamed, they were correct in only 11 of 43 cases, yielding a negative predictive value of only 26%. These authors suggest that during a laparoscopic operation for presumed appendicitis, the normal-appearing appendix should be removed.[21]

In conclusion, although controlled studies have demonstrated a decrease in the frequency of misdiagnosis with CT, US, and laparoscopy, we identified no change in the misdiagnosis of appendicitis on a population level concurrent with the increasing availability of this diagnostic technology. We recommend further investigation of the pragmatic relationship between diagnostic tests for presumed appendicitis and diagnostic accuracy at appendectomy. Finally, this study indicates that the general population has not realized one suggested benefit of the era of advanced diagnostic testing: the reduction of unnecessary appendectomies.

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Acquisition of data: Flum.
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Drafting of the manuscript: Flum, Morris.
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Administrative, technical, or material support: Morris.
Study supervision: Dellinger.

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