Management of Asymptomatic Gallstones in the Diabetic Patient

A Decision Analysis

Lawrence S. Friedman, MD; Mark S. Roberts, MD, MPP; Allan S. Brett, MD; and Keith I. Marton, MD

The management of asymptomatic cholelithiasis in patients with diabetes is controversial. We used decision analysis to compare expectant management to prophylactic cholecystectomy in asymptomatic diabetic patients. Relevant probabilities were derived from the literature or expert opinion. Hypothetical cohorts of patients were followed for their lifetimes under each strategy. Expectant management was almost always the superior course. For example, a 30-year-old diabetic man gains an average of 6.1 months of life by choosing expectant management over prophylactic surgery. The superiority of expectant management was invariant to changes in age, sex, and the extent to which major surgical complications affect the future quality of life. Prophylactic cholecystectomy was superior only with extremely high estimates of the likelihood of developing symptomatic disease, the probability of requiring emergency surgery after symptoms develop, and emergency surgical mortality rates. However, no single factor had sufficient impact to alter the optimal decision by itself; the probabilities of several untoward events had to be increased simultaneously to favor prophylactic cholecystectomy. Prophylactic surgery for silent gallstones in diabetic patients does not increase life expectancy or quality of life and may in fact reduce it. This result holds over a wide range of basic assumptions.

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From New England Deaconess Hospital and Harvard Medical School, Boston, Massachusetts. For current author addresses, see end of text.

Cholelithiasis is a common condition (1, 2) for which at least one half million people have a cholecystectomy in the United States annually (3). At one time cholecystectomy was recommended even for patients in whom gallstones were asymptomatic (4, 5), because prophylactic surgery was assumed to prevent excess morbidity from subsequent symptomatic gallstone disease. With few exceptions this management approach has been abandoned. It is now known that relatively few people with gallstones develop symptoms (6, 7), and when they do, emergency surgery is usually not necessary (6-8). Moreover, the operative mortality from emergency surgery is low (9).

One common exception to this change in philosophy occurs for the diabetic patient. There is a perception, primarily based on data that is several decades old (10-13), that diabetes confers intolerable operative morbidity and mortality if acute cholecystitis develops. Because the medical and economic costs of subjecting this group of patients to prophylactic surgery are high, a more careful evaluation of prophylactic surgery is warranted. Short of a natural history study, which has not been done, the best evidence that the problem needs rethinking comes from recent retrospective data (9, 14, 15) that suggests that diabetic patients tolerate biliary tract surgery in a manner similar to the general population.

Decision analysis, by allowing variation of event probabilities, is a technique that can illuminate the factors most relevant to a complex decision (16). We used this technique to assess whether or not a diabetic patient with asymptomatic gallstones should have prophylactic cholecystectomy.

Methods

A model was constructed to describe the possible outcomes of each choice of therapy. Because the final consequences of the initial choice of therapy can be manifested at various future times, standard decision analysis methodology (16) was extended through the use of Markov processes to allow for adjustments in probabilities over time (17). In addition, sensitivity analysis was done to test the stability of our analysis to variations in both probability and outcome estimates.

The Decision Model

The initial decision for a diabetic patient with asymptomatic gallstones is a choice between elective cholecystectomy or expectant management. The consequences of these two management choices are shown in Figure 1 (*see* Appendix for greater detail). If elective surgery is chosen (Figure 1, *top*), the patient may die at surgery, sustain a major or minor complication, or have successful, uncomplicated surgery. For patients who survive, their remaining lifetime is modelled by a series of two-state Markov processes, in which the patient either survives or dies of other causes in any given year. If expectant management is chosen (Figure 1, *bottom*), the patient may remain asymptomatic, develop symptoms, or die from other causes. If symptoms develop, it is assumed that the patient will require either elective or emergency surgery. Although the probabilities differ, the three surgical consequences (death, survive with complications, and survive without complications) are the same for elective and emergency surgery.

With either management choice, it is assumed that after surviving surgery the patient will be free of any biliary tract

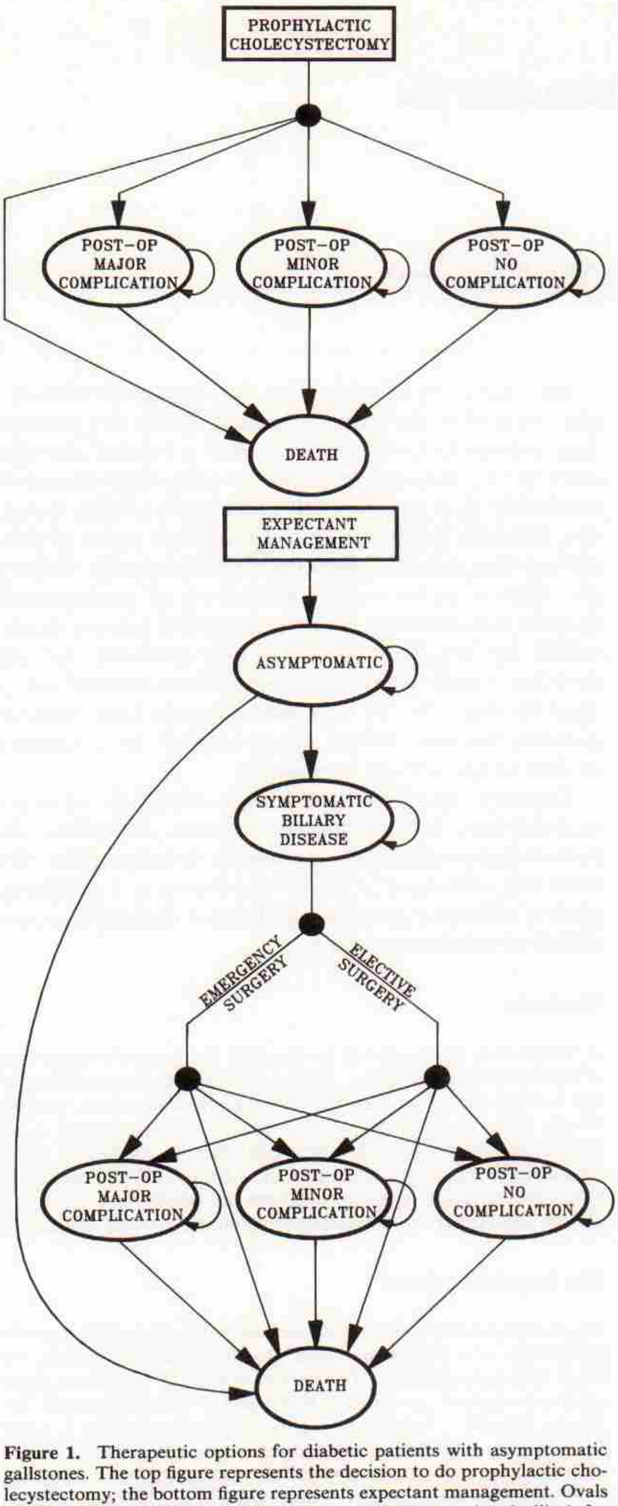

Figure 1. Therapeutic options for diabetic patients with asymptomatic gallstones. The top figure represents the decision to do prophylactic cholecystectomy; the bottom figure represents expectant management. Ovals represent Markov states, and are characterized by a value (utility) for being found in that state for one time period (1 year in our analysis) and a probability (*arrows*) describing the likelihoods of progressing to other states. Arrows that point to the same state represent the probability of remaining in that state from one year to the next. Dark circles represent chance nodes. For the decision to do prophylactic cholecystectomy, in any given year after surgery a patient either remains in their particular post-operative state or dies of unrelated causes. For expectant management, patients either remain asymptomatic and eventually die of unrelated causes or develop symptoms. If symptoms develop, they may have elective or emergency surgery from which they will survive with or without complications or die. If they survive surgery, they remain within their specific post-operative state until death from other causes occurs. These processes continue until the entire cohort dies.

disease. After surgery, the probability of death from other causes varies with age, sex, and whether or not the patient sustained a major complication.

Probabilities

The analysis requires estimates of the rate at which patients become symptomatic, the likelihood of requiring emergency surgery after becoming symptomatic, and the operative mortality and morbidity for elective and emergency cholecystectomy. Because the analysis continues for the lifetime of the patient, and these probabilities may vary with age, age-specific probability estimates are required.

Table 1 shows the likelihoods of developing symptoms over time, and was based on published data (6) on the natural history of silent gallstones in the nondiabetic patient. Although it is known that diabetic patients have an increased incidence of cholelithiasis (18, 19), it is not known whether they become symptomatic more frequently than nondiabetic patients (20). We asked a panel of expert surgeons and gastroenterologists whether, in their experience, diabetic patients developed biliary symptoms more frequently than nondiabetic patients. Several felt that there was no difference in likelihood of symptom development, and some felt than there was perhaps an increased risk. Initially, this analysis assumes that diabetic patients have the same annual symptom-development rate as nondiabetic patients. The impact of this assumption was tested using sensitivity analysis.

Operative mortality and morbidity are based on published data (9, 14, 15, 21-24) for complication rates of biliary tract surgery in diabetic patients and the elderly. This data is shown in Table 2. The literature regarding these complication rates has changed. Earlier studies (11) cited mortality rates as high as 31% for cholecystectomy in diabetic patients. Most recent data (9, 15, 21) suggest nearly identical mortality rates for diabetic patients and nondiabetic patients having cholecystectomy for acute cholecystitis. Our analysis used probabilities reflecting the more recent experience. In addition, as a confirmation of our literature review, we asked senior surgical staff at our institution (where there is a large experience with surgery in diabetic patients) to provide their estimates of operative mortality and morbidity for male and female diabetic patients of various ages, having both emergent and elective operations. Their estimates were generally in close agreement with the published literature of recent years. In diabetic patients who develop acute cholecystitis, the likelihood that emergency surgery will be required is unclear. Using the experience of our expert surgical consultant, the probability of this event was estimated to range from 12.5% in a 30-year-old diabetic patient to 30% by age 60.

Table 1. *Incidence of Developing Symptomatic Biliary Disease in Non-Diabetic Patients with Known Asymptomatic Gallstones**

Years Since Diagnosis	Yearly Incidence	Cumulative Incidence
1	0.044	0.044
2	0.024	0.067
3	0.022	0.087
4	0.015	0.101
5	0.012	0.112
6	0.011	0.121
7	0.010	0.130
8	0.009	0.138
9	0.009	0.146
10	0.009	0.154
11	0.009	0.161
12	0.008	0.168
15	0.005	0.183
20	0.001	0.193
30	0.000	0.199

* This table was adapted from reference 6.

Life expectancy tables do not exist for diabetic patients. Because diabetes is often not listed as an underlying factor on death certificates, true death rates for diabetic patients are not well defined (25, 26). We therefore used age-specific death rates for standard populations published by the National Center for Health Statistics (27) and multiplied these rates by three to account for the higher death rates seen in diabetic patients. Although this estimate of increased mortality is somewhat arbitrary, it yields a life expectancy for diabetic patients approximately 5.9 to 11.7 years shorter than nondiabetic patients (depending on age), consistent with the experience of physicians who care for large numbers of diabetics. The impact of this assumption was tested by sensitivity analysis.

Outcome Measures

The standard outcome measure used in this analysis is life expectancy. Life expectancy is calculated from the average "lifetimes" of the persons who proceed through the model, which uses yearly death rates (based on published age-and sex-specific mortality rates) to estimate the annual probability of death (27).

There are two potential problems with this simple model. First, the long-term life expectancy of patients surviving surgery with a major complication (for example, myocardial infarction or stroke) might be reduced. Second, the long-term quality of life of patients surviving surgery with these complications might be diminished; the life expectancy of such patients therefore should be weighted according to the subjective value a patient places on being alive in a less-than-optimal state of health. Because both of these adjustments are not easily determined, we used our own intuitive estimates for these adjustments: Mortality rates were multiplied by 1.5 for patients with a major complication. Minor complications prolonged hospitalization and affected short-term quality of life but did not affect mortality. These estimates were then varied over a wide range of clinically plausible values.

Calculations

Tree design and analysis was done on an IBM XT computer using the *SMLTREE* decision analysis program (Jim Hollenberg, New York, New York). Analyses were done for men and women with gallstones discovered at the beginning of the third, fourth, fifth, sixth, and seventh decades of life. Outcomes were analyzed using both simple life expectancy and quality-adjusted life expectancy to account for the difference in value of a year of life spent after the occurrence of various potential operative complications. Because adjustments for quality of life did not alter the result, only that part of the analysis based on unadjusted life expectancy is presented here.

Sensitivity analysis was done to determine the stability of the results over ranges of estimates and to determine those variables that have a significant impact on the proper choice of therapy. Initially, threshold analysis were done on each variable to determine if any reasonable estimate of that variable's probability carried sufficient weight to alter the optimal decision. Two- and three-way analyses were then done on combinations of those variables to provide graphic representations of the specific consequences of altering these probabilities. Finally, Monte Carlo sensitivity analysis (*see* Appendix) was used to determine the stability of the results to simultaneous errors in our estimates of several of the important probabilities.

Results

The basic results are shown in Table 3. Our analysis shows that expectant management yields greater life expectancy regardless of the age at which gallstones are discovered, and that these results are similar for men and women. For example, a 30-year-old man gains an average of 0.51 years (6.1 months) of life by choosing expectant management over prophylactic surgery; a 30-year-old woman gains 0.47 years (5.6 months). The relative advantage of expectant management increases with age and peaks for men in the sixth decade of life, where the advantage of waiting increases to 0.69 years (8.2 months). The fifth decade was the peak for women and resulted in 0.61 years (7.3 months) gained.

Sensitivity analysis shows that these results are extremely stable over large ranges of values for the various mortality, morbidity, and incidence rates. For individual probabilities, threshold analysis showed that no single factor was powerful enough to reverse the superiority of expectant management over prophylactic surgery. However, combinations of factors, if simultaneously different from the baseline assumptions, were able to shift the balance in favor of prophylactic surgery.

The major difference between the two clinical strategies is the excess mortality and morbidity that occur in that portion of patients who become symptomatic and

Table 2. *Risks of Cholecystectomy in Diabetic Patients: Literature Estimates**

Age/Sex	Emergency Surgery Complication			Elective Surgery Complication		
	Mortality	Major	Minor	Mortality	Major	Minor
30/M	0.03	0.10	0.20	0.01	0.08	0.10
30/F	0.02	0.08	0.18	0.01	0.06	0.10
40/M	0.04	0.14	0.25	0.01	0.12	0.18
40/F	0.03	0.12	0.22	0.01	0.10	0.16
50/M	0.045	0.20	0.28	0.015	0.18	0.25
50/F	0.04	0.17	0.24	0.015	0.15	0.20
60/M	0.05	0.27	0.33	0.020	0.25	0.30
60/F	0.045	0.22	0.28	0.015	0.20	0.25
70/M	0.07	0.33	0.39	0.03	0.30	0.35
70/F	0.05	0.29	0.32	0.02	0.27	0.30

* Probabilities between the decades, as well as probabilities for patients over age 70, were determined by linear extrapolation. Data from references 9, 14, 15, and 21-24.

Table 3. *Remaining Years of Life Expectancy by Age, Sex, and Choice of Therapy: Cholecystectomy Compared with Expectant Management*

Age/Sex	Expectant Management	Prophylactic Surgery	Difference
30/M	30.47	29.96	0.51
30/F	37.04	36.57	0.47
40/M	22.08	21.54	0.54
40/F	28.02	27.54	0.48
50/M	14.72	14.04	0.68
50/F	19.94	19.33	0.61
60/M	9.06	8.37	0.69
60/F	13.10	12.54	0.56
70/M	5.22	4.64	0.58
70/F	7.71	7.22	0.49

require emergency surgery. This increased risk is partially balanced by those patients in the prophylactic surgery arm who would never have developed biliary symptoms, but who are exposed to an operation and its attendent risks. The intuitive conclusion, born out by the sensitivity analysis, is that the optimal choice of therapy is dependent on the rate at which diabetic patients develop symptoms; the probability of requiring emergency surgery once symptomatic; and the mortality rate during emergency surgery.

Figure 2 shows the influence of these three variables on the optimal choice of therapy. For any combination of possibilities for these variables, the figure enables one to select the optimal therapeutic strategy. The probabilities of requiring emergency surgery (vertical axis) and the mortality of emergency surgery (horizontal axis) represent probabilities that would apply if the patient developed symptoms at the time of initial diagnosis of gallstones. Our model accounts for the fact that these likelihoods increase over time (Table 2). The three-way sensitivity analysis shows that for large ranges of values for the risks of emergency surgery and the likelihood of requiring it, expectant management is superior to prophylactic cholecystectomy. Specifically, even in a patient with a lifetime cumulative incidence of developing symptoms of 50%, the probability of requiring emergency surgery and the operative mortality for diabetic patients must exceed the nondiabetic population by a factor of 2.5 to 3 for prophylactic surgery to be the preferred strategy.

Sensitivity analysis also showed that this result is insensitive to the magnitude of difference in average life expectancies of diabetic patients compared with nondiabetic patients. The annual mortality data in this analysis were derived from life-tables for the general white American population, with a multiplicative weight (set at 3) for the excess risk for death (for example, from cardiovascular disease, infection, and peripheral vascular disease) that is associated with diabetes. Varying this mortality weight from 1 to 25 times the annual mortality of a nondiabetic patient did not change the superiority of expectant management over prophylactic surgery. This result is not surprising, because poor life expectancy affects the average value of both choices (surgery and waiting) approximately equally.

Monte Carlo sensitivity analysis also supported the stability of the baseline results (*see* Appendix). Probability distributions were estimated for the likelihood of developing symptoms, the probability of emergency surgery, and the mortality and morbidity of emergency surgery, using our baseline estimates as the means. The tree was evaluated thousands of times with randomly selected values from each of these distributions, which allowed wide ranges of errors in individual probability estimates. The analysis found expectant management to be superior in 98.7% of its iterations.

Mortality is not the only major risk of emergency surgery. Surgical complications can substantially affect future life expectancy and the quality of that life, and complication rates of emergency surgery exceed rates of elective surgery. Therefore, it is easy to understand why a prophylactic strategy that avoids emergency surgery is often recommended. However, inclusion of post-complication adjustments to both the quality of life and future mortality actually strengthens the superiority of expectant management. This result occurs because elective surgery is not totally without risk. Therefore, the number of major complications resulting from early prophylactic surgery on an entire population exceeds the number of complications resulting from emergency surgery on that fraction of the population that becomes symptomatic and fails standard medical therapy. This result is stable over all ranges of quality of life adjustment.

Discussion

Our analysis shows that a strategy of expectant management is consistently superior to prophylactic sur-

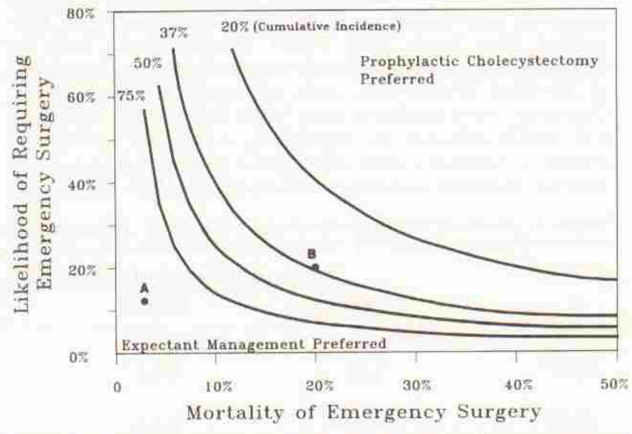

Figure 2. Influence of three variables on the preferred management of asymptomatic gallstones in a 30-year-old man with diabetes. The horizontal and vertical axes show ranges of mortality at emergency surgery and the likelihood of requiring emergency surgery, respectively. The four curves display cumulative lifetime incidences of developing symptoms. Points lying above any cumulative incidence line favor prophylactic surgery, points below favor expectant management. Point A indicates our best estimate for the probabilities associated with a 30-year-old diabetic man; expectant management is always preferred regardless of the cumulative incidence of symptom development. However, if a hypothetical patient had a 20% surgical mortality and a 20% chance of requiring emergency surgery (point B), the decision is strongly dependent on the incidence of developing symptoms: Prophylactic surgery is preferred when the cumulative incidence exceeds approximately 37%.

gery in diabetic patients with asymptomatic gallstones. This conclusion does not change over a broad range of assumptions about the rate of developing symptomatic disease, the likelihood of emergency surgery in a symptomatic patient, and the mortality and morbidity of emergency surgery.

Although we believe that the analysis favors expectant management for most patients with diabetes, we do not exclude the possibility that certain patients will benefit from prophylactic surgery. If, for example, a patient was felt to have an unusually high risk for developing symptomatic disease and an exceptionally poor tolerance for emergency surgery, the optimal strategy might shift to prophylactic surgery. An example of such a patient is provided in the legend of Figure 2. However, our analysis strongly suggests that no single factor should push the decision in favor of surgery.

These results agree with similar analyses of the optimal management of asymptomatic gallstones in nondiabetic patients (18, 28, 29). However, they differ from the currently accepted clinical practice of recommending prophylactic surgery in asymptomatic diabetic patients (30). The potential reasons for this discrepancy might include inaccurate or out-dated information on the risks of surgery in diabetic patients, and uncertainty regarding the natural history of gallstones in such patients. Our analysis found that there are circumstances under which prophylactic surgery could be the optimal therapy, but they require the lifetime incidence of developing symptoms to exceed 50%, the need for emergency surgery to range from 30% to 75% depending on age, and the operative mortality to be in the range of 9% to 21%, again depending on age at surgery.

Neither recent retrospective studies nor the surgical staff at our institution would assign such a high probability of emergency surgery or of dying at that surgery (9, 14, 15). We suspect that several recent developments have resulted in more favorable management of acute cholecystitis. Ultrasonography has improved the ability to diagnose cholelithiasis rapidly and accurately; new broad-spectrum antibiotics have increased the effectiveness of medical management; and intraoperative monitoring techniques have decreased the risk for hemodynamic complications.

Decision analysis models often omit details of the management of a particular disease for computational simplicity. Several therapies and potential consequences have been ignored by our analysis, but they are unlikely to alter the basic result, either because their effects are extremely small compared with the strength of the result, or because the particular techniques or therapies are still sufficiently experimental to preclude strong statements about their effectiveness. For example, pharmacologic dissolution of gallstones (which completely or partially dissolve stones in 15% to 40% of patients) was not considered in our analysis (31-33). Lithotripsy and percutaneous transhepatic gallbladder puncture and stone dissolution with injected methyl-tert-butyl ether are also under study (34-36). These are new and experimental therapies for which reliable data are not available. However, to the extent that these modalities are successful, they would certainly mitigate against prophylactic surgery.

Our analysis made no distinction between type I and type II diabetic patients. One would expect that a 40-year-old woman with 3 years of diet-controlled diabetes might have significantly different risks and benefits compared with a 40-year-old woman with 35 years of insulin-dependent diabetes. We attempted to account for this problem by making more conservative (that is, higher) estimates for morbid events than one finds in the general population, reflecting the higher incidence of cardiovascular and renal disease in this population. Because the results strongly support expectant management in "high-risk" diabetic patients, the same conclusions should be even stronger for "healthier" diabetic patients.

The risk for developing gallbladder cancer in patients with cholelithiasis was also not included in the standard analysis. This risk is relatively small, is most common in the elderly, and may be increased only in men (2). However, because it only affects the expectant management branch of the tree, it may have the potential to change the optimal decision. Moreover, there is still controversy as to whether cholecystectomy increases the rate of developing other gastrointestinal malignancies such as colon cancer (2, 37, 38). We recreated the decision analysis including the possibility that a patient followed by expectant management might develop gallbladder cancer. Of patients who develop gallbladder cancer, the model assumed 95% of them would die within the next 5 years. With our other assumptions left unchanged, the lifetime incidence of developing gallbladder cancer must exceed 2% before prophylactic surgery might become the superior choice of therapy. Because this rate exceeds estimates found in the literature (2, 39), and because the distribution of risks across ages is unknown but likely to be weighted toward the elderly, it is unclear how this would affect persons who have a baseline decreased life expectancy.

Pancreatitis is a complication of both cholelithiasis and cholecystectomy (15, 30, 40, 41), and therefore it may occur with either expectant management or prophylactic surgery. The actual direction this factor would push the analysis depends on the relative magnitudes of developing the condition under either course of action. Because this difference is most likely quite small, we have not explicitly added the risk for developing pancreatitis to the analysis.

Cost benefit analysis and discounting of the future costs and benefits were not done. The economic cost of doing indiscriminate prophylactic cholecystectomy would almost certainly exceed the cost of expectant management. Discounting, which weighs present costs greater than future ones, would even further weight the outcome toward expectant management, already a strongly supported decision.

The management of asymptomatic gallstones should be similar in patients with and without diabetes. Prophylactic surgery for silent gallstones in diabetic patients does not increase life expectancy or the quality of life and may in fact reduce it. Moreover, this result holds over a wide range of basic assumptions.

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Requests for Reprints: Lawrence S. Friedman, MD, Section of General Internal Medicine, New England Deaconess Hospital, Suite LMOB 7H, 185 Pilgrim Road, Boston, MA 02215.

Current Author Addresses: Drs. Friedman, Roberts, Brett, and Marton: Section of General Internal Medicine, New England Deaconess Hospital, Suite LMOB 7H, 185 Pilgrim Road, Boston, MA 02215.

Appendix

The Decision Model

The problem examined in this paper involves modeling several future events such as the development of biliary symptoms, the need for and outcome of emergency surgery, and death from natural causes. Moreover, the likelihood of any of these events occurring varies over time, and may change depending on what events have already happened to any particular patient. The time-varying nature of these probabilities mandates the use of a modelling process that allows for several factors to change over time. Therefore, the model is a combination of standard decision analysis extended with the use of Markov processes. Patients' lifetimes are modeled as a series of "states," such as asymptomatic, alive post-operatively, dead, and so forth. A state is defined by a value for being found in that state for one time period (a year in our analysis), and by a set of probabilities that govern the likelihood of transition between states. Certain events, such as the requirement for emergency surgery once symptoms develop, are modeled as standard decision analysis chance nodes as they are assumed to involve no significant passage of time and carry no intrinsic value of their own. To estimate expected survival, a hypothetical cohort of patients is followed through time; patients still surviving continue to live on, become symptomatic, or die from other causes. The process continues until all patients in the cohort die; expected survival is simply the average lifespan of members of that cohort.

The initial decision is a choice between prophylactic cholecystectomy (Figure 1, *top*) or expectant management (Figure 1, *bottom*). If prophylactic cholecystectomy is chosen, patients will either die during surgery (DEATH state) or they will survive. If they survive, they may do so without complication (POST-OP NO-COMPLICATION state), or may sustain a major or minor complication (POST-OP MAJOR COMPLICATION or POST-OP MINOR COMPLICATION state). A major complication is defined as a nonreversible untoward event such as a myocardial infarction or stroke, and is assumed to affect the patient's future life expectancy by increasing the age-specific annual death rates used to determine long-term survival. A minor complication prolongs hospital stay or recovery time but has no significant effect on long-term mortality. Because the effect is transient, the consequence of a minor complication only effects the value of the post-operative minor complication state for one time period. After that, recovery is assumed, and the value of being post-operative with a minor complication is equivalent to having had no complications during surgery.

Regardless of complication, operative survival implies that the patient is cured of biliary tract disease. The three possible post-operative conditions are modeled as simple two-state Markov processes. Therefore, in any given future year, the patient either remains alive in a particular post-operative state or dies from other causes. The relative likelihoods of these events will vary with sex, age, and whether the patient sustained a major complication during surgery.

If expectant management is chosen, several scenarios are possible, and are modeled as a six-state Markov process (Figure 1, *bottom*). Patients are assumed to initially be asymptomatic, and in the subsequent year may remain asymptomatic (ASYMPTOMATIC state), become symptomatic with biliary disease (SYMPTOMATIC BILIARY DISEASE state) or die from other causes (DEATH state). If the patient becomes symptomatic, the analysis assumes that in a portion of the patients, medical management (intravenous antibiotics, hydration, and so forth) will "cool down" the acute episode, enabling the patient to have later elective cholecystectomy (ELECTIVE SURGERY branch). Alternatively, either because of the failure of medical management, or due to appropriate initial clinical indications, some patients will require emergency surgery (EMERGENCY SURGERY branch) shortly after becoming symptomatic. In addition to a successful outcome, either surgery (elective or emergency) carries the possibility of death or a major or minor complication. The likelihoods of poor outcomes vary with age and sex and are higher for emergency surgery (Table 2).

As in the prophylactic cholecystectomy choice, patients who survive surgery are assumed to be free of biliary tract disease but subject to death from other causes. They continue to live in one of three specific post-operative states, depending on whether they had uncomplicated surgery or sustained a major or minor operative complication (POST-OP NO COMPLICATION state, POST-OP MAJOR COMPLICATION state, or POST-OP MINOR COMPLICATION state). The age- and sex-specific natural mortality rates are increased in patients who have sustained a major complication; they are unadjusted for patients who survived surgery without complication or sustained only a minor complication.

Monte Carlo Sensitivity Analysis

Monte Carlo analysis allows for the fact that the probabilities used in decision analysis are only estimates; the real values for an individual or population may be quite different. For several uncertain values in the decision tree, we specified distributions (log-normal or uniform) centered around our "best estimates" as derived from the literature and our discussions with ex-

Appendix Table 1. *Monte Carlo Parameters* *

Variable	Baseline	Minimum	Maximum	Distribution
PSYMP	1.0	1.0	4.0	Uniform
PEMERG	1.0	0.8	4.0	Uniform
EMMORT	1.0	0.5	4.0	Log normal
EMMAJOR	1.0	0.5	4.0	Log normal
MADJMAJ	1.5	1.0	2.0	Uniform

* PSYMP = probability of developing symptoms; PEMERG = probability of requiring emergency surgery when symptomatic; EMMORT = mortality of emergency surgery; EMMAJOR = probability of major complication at emergency surgery; MADJMAJ = mortality adjustment factor after a major complication at surgery.

perts. The tree was then recalculated thousands of times. Each time a different estimate of each probability was randomly drawn from the distributions that we had specified. Estimates based on sound data were given distributions with very little variance, and less certain estimates were given wider ranges of potential values. An estimate of the stability of the analysis to simultaneous errors in selected probabilities is shown by the percentage of times that the choice of optimal therapy changes from the baseline estimates.

Appendix Table 1 lists the variables included in our Monte Carlo analysis. The baseline, minimum, and maximum values are expressed as multiples of our baseline assumptions. For example, the probability of developing symptoms (PSYMP) was assumed at baseline to be equivalent to the rate for nondiabetic men. The Monte Carlo analysis ranged from 1 to 4 times that value, with a log-normal distribution. Monte Carlo simulations showed that with random sampling from the five distributions in the table, expectant management is the superior choice in 98.7% of the iterations.

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