APPENDIX B: AN ANALYSIS OF ELECTIVE HYSTERECTOMY AND TUBAL LIGATION

Introduction

The purpose of this analysis is to compare the length of life and direct medical expenditures for a woman undergoing either elective hysterectomy or tubal ligation on her 35th birthday. This comparison is based on the estimation of the probability that the woman's lifetime equals a specific length and the probability that direct medical expenses equals a specific amount, given her choice of sterilization procedure. These estimates are based on an analysis that incorporates the influence of controlled events (e.g., elective surgery) and uncontrolled events (e.g., the development of cancer) on life expectancy.

In order to simplify the analysis, it will be assumed that all events significant occur on the patient's birthday. Therefore, at precisely 12-month intervals, the woman undergoes surgery, is diagnosed and treated for disease, and risks dying from the various causes of death to which she is exposed. This assumption reduces the field of interest to a finite number of points in the woman's life. The other assumptions incorporated in the analysis are described in the next section below.

Given the complete history of events that actually do occur on a woman's birthdays, it is possible to determine the total direct cost of her gynecologic care. Thus, the analysis computes the probability that direct costs equal a particular value by surveying the probability of all possible histories that correspond to that level of cost. Future costs are discounted according to a fixed estimate for the real interest rate.

Assumptions

A response to future events in one's life can vary from one individual to another. Furthermore, when several alternatives are available, it is often difficult to state with certainty in advance of the actual decision which alternative will be chosen. However, for the sake of simplicity, it will be assumed that the following decisions are made conditional on corresponding events.

If a woman becomes pregnant after tubal ligation, she will undergo abortion and repeat sterilization. It will be assumed that any pregnancies after tubal ligation occur 1 year after the procedure. It will also be assumed that subsequent tubal ligations do not fail.

If any uterine cancer develops in a woman after tubal ligation, then she will undergo hysterectomy as part of her therapy. Admittedly, many cancers are often treated without surgery, particularly cervical cancers detected in situ. Nevertheless, so as to simplify the analysis, it will be assumed that surgery is indicated in the treatment of uterine cancer. Sensitivity analysis indicates that this assumption does not affect the comparison. Furthermore, it is not unreasonable to expect that a woman who has previously undergone a sterilization procedure will undergo hysterectomy after the subsequent detection of cancer.

Finally, it will be assumed that causes of death are independent. Therefore, reducing the chance of death from one cause does not disproportionately increase the chance of death from another cause. This independence assumption can be expressed mathematically as follows. Suppose that all possible causes of death have been lumped together into "n" groups. For example, the jth group might be all uterine related causes of death. Let "P(i,j)" denote the probability that a woman dies on her ith birthday from the jth cause (actually, a cause from the jth group). Then "P(38,j)" would denote the probability of death from uterine disease on a woman's 38th birthday. The independence assumption is then:

$$\text{Probability of death at ith birthday from jth cause given did not die from kth cause} = \frac{P(i,j)}{1 - P(i,k)}$$

In general, this independence assumption does not always hold—e.g., consider a very risky surgical procedure which is only performed for a disease that is always fatal if not cured. Let death from the surgical procedure denote one cause of death and death from the disease another. If the surgery is always attempted as a final effort to save the patient's life, then few patients would actually die from the disease itself. On the other hand, eliminating one cause of death by either discontinuing the surgery or else preventing the disease by some other approach will disproportionately alter the probability of the other cause of death. Therefore, these two causes of death are dependent.

This analysis will consider the following groupings of causes of death:

- uterine cancers,
- complications during hysterectomy,
- complications during tubal ligation,
- complications during abortion,
- complications during dilatation and curettage, and
- all other causes of death.

Dependencies between the first and second causes of deaths are eliminated in the analysis by combining deaths due to uterine cancer with deaths during therapeutic hysterectomy.

The Woman Undergoing Hysterectomy

The woman who undergoes elective hysterectomy faces only two causes of death from the list above: 1) death as a result of the procedure, or 2) death from the "other" causes (which exclude gynecologic causes). The age-specific risk of death during hysterectomy was obtained from The National *Halothane* Study (18). The overall death rate for low-risk surgical operations was observed to be *23* deaths per 10,000 procedures, which equaled the weighted average for mortality rates in 12 studies (24). Thus, it was assumed that the age-specific death rate for death from hysterectomy matched that for all low-risk procedures.

Age-specific surgical mortality rates for hysterectomy

Age	*Deaths/10,000*
30	8.9
40	14.5
50	33.9
60	54.1
70	116.5
80	281.8
90	500.0
100	500.0

The age-specific mortality rates for nongynecologic death was determined from the *Vital Statistics of the United States* for 1976 (58).

Age-specific nongynecologic annual death rates

Age	*Deaths/100,000*
30	68
35	93
40	146
45	244
50	381
55	586
60	931
65	1,336
70	2,095
75	3,678
80	6,125
100	15,932

Let the following symbols denote the probability for the respective events on the 35-year-old woman's ith birthday:

Symbol	*Event*
A	Alive at start of birthday
L	Death during birthday
R	Risk from hysterectomy
M	Nongynecologic mortality rate

then:

$$A(i) = A(i-1) - L(i-1), \text{ with } A(35) = 1$$

That is, the probability of being alive on her ith birthday equals the probability of being alive on her i-1st birthday minus the probability of dying on her i-1st birthday. If the woman undergoes elective hysterectomy, then:

$$L(35) = R(35) + M(35)$$

Therefore, during subsequent years the probability of death on a particular birthday can be computed from the following equation:

$$L(i) = A(i) \times M(i)$$

The Woman Undergoing Tubal Ligation

Lower mortality rates are observed for tubal ligation than for elective hysterectomy. Deane and Ulene (24) reported that the weighted average tubal ligation mortality rate for 13 studies was 12 deaths per 10,000 patients. This is approximately half of the weighted average hysterectomy mortality rate. Therefore, the age-specific mortality rate for tubal ligation was estimated by halving the rates reported by The *National Halothane Study* for low-risk procedures (18).

Age-specific surgical mortality rates for tubal ligation

Age	*Deaths/10,000*
30	4.5
40	7.2
50	16.9

Therefore, since it is assumed that the woman has no gynecologic diseases, the probability of death during her 35th birthday can be computed as follows:

$$L(35) = T(35) + M(35),$$

where T(i) is the mortality rate for tubal ligation at age i.

During the following year, the tubal ligation may fail. McElin, et al. (51) reported a subsequent pregnancy in 5 of *902* patients sterilized by the Pomeroy technique. Therefore, a failure rate of 5 per 1,000 was used in the analysis. It was assumed that pregnancy, if it occurred, did so in the year following the procedure. The unsuccessful tubal ligation was followed by a repeat of the procedure together with a dilatation and curettage. The age-specific risk of death for this combined procedure was approximated to be the same mortality rate assumed for tubal ligation.

Women choosing tubal ligation are subjected to a variety of other risks besides subsequent pregnancy. The risk of death on any particular birthday is computed by adding the risk of death from each particular cause. The nongynecologic causes comprise one group of risks. As before, the risk from nongynecologic causes is estimated by multiplying the probability of being alive by the age-specific mortality rate:

$$\text{Risk of death from nongynecologic causes} = A(i) \times M(i)$$

In order to be exposed to a gynecologic cause of death, a woman must not have previously undergone hysterectomy. Let H(i) denote the probability of undergoing hysterectomy on ith birthday for an indication, and let B(i) denote the probability of living until the start of ith birthday without previously undergoing hysterectomy. Then:

$$B(i) = B(i-1) - H(i-1)\,[1-R(i-1)] - L(i-1),$$

where R is the age-specific risk from hysterectomy and L is the probability of death on the ith birthday. In other words, the probability of being alive with a uterus still intact on one's ith birthday equals the probability of being alive with a uterus intact at the previous birthday minus the probability of death or hysterectomy during the previous birthday.

In this analysis, the indications for hysterectomy are divided into two groups: cancer and noncancer. The age-specific incidence of noncancer hysterectomies was determined from unpublished data from the National Hospital Discharge Survey (57) and the findings reported by Ledger and Child (47) from their study of *12,026* hysterectomies.

Age-specific hysterectomy rate for causes other than cancer

Age	*Procedures/10,000*
30	94
40	177
50	124
60	49
80	26
100	0

Recall that the analysis assumed that hysterectomy was performed for all women in whom uterine cancer is diagnosed. Therefore, the rate of hysterectomy for cancer equals the age-specific incidence of the disease. The analysis aggregated the various stages and sites for uterine cancer into three groups: 1) localized cancer of the cervix uteri, 2) invasive cancer of the cervix uteri, and 3) cancer of the corpus uteri. Age-specific rates reported by Kim, et al. (42) were used:

Age-specific incidence for uterine cancers

Age	*Localized cervical*	*Invasive cervical*	*Corpus*
30	126.2	11.6	1.5
35	72.3	10.8	6.2
40	50.3	16.8	14.4
45	19.2	24.0	32.4
50	19.6	35.3	53.6
55	10.2	21.9	45.2
60	11.6	21.6	73.1
65	12.5	22.9	74.9
’70	10.0	14.8	91.6
75	6.1	15.2	61.0
		15.2	61.0

If $I_1(i)$, $I_2(i)$, and $I_3(i)$ denote the incidence of localized cervical, invasive cervical, and corpus uteri cancer, respectively, then the probability that a woman undergoes hysterectomy on her ith birthday is:

$$H(i) = B(i) \times [U(i) + I_1(i) + I_2(i) + I_3(i)],$$

where U(i) is the incidence of hysterectomy for nonmalignant diseases. This includes elective procedures.

The risk of death on a woman's ith birthday can then be computed as follows:

Probability of death from hysterectomy on ith birthday = $H(i) \times R(i)$

A woman who has not undergone hysterectomy may also develop excessive bleeding that warrants dilatation and curettage, which implies a small risk. Rates for dilatation and curettage were determined from Deane and Ulene (24):

Age-specific frequency of undergoing dilatation and curettage

Age	*Procedures/10,000*
≤ 50	16
>50	4

Age-specific death rates from this procedure were approximated by the risks during abortion. Therefore, if G(i) denotes the age-specific risk during abortions and J(i) the age-specific frequency, then:

Probability of death from dilatation and curettage = $B(i) \times J(i) \times G(i)$

Finally, some of the women who choose tubal ligation will die from uterine cancer. The survival of these patients after diagnosis depends upon the location and extent of their disease. In this analysis, these survival rates were estimated from data reported in *Recent Trends in Survival of Cancer Patients (5)* for the years 1960 to 1971.

Probability of death from uterine cancer after various numbers of years

Years	*Localized cervical*	*Invasive cervical*	*Corpus*
1	*0.06*	*0.19*	0.11
3	0.05	0.09	0.05
5	0.02	0.05	0.03
10	0.01	0.01	0.02

It was assumed that if a patient died from uterine cancer, then the death occurred within 10 years of the initial diagnosis.

The probability of death from a particular type of cancer diagnosed k years earlier equals the probability that the cancer was discovered at that time, times the probability that the patient survived the initial therapy and subsequent risk, times the probability of death from that cancer k years after it is diagnosed. The probability of death from all cancers on a particular birthday then equals the sum of all three cancers for the previous 10 years.

Cost of Gynecologic Care

The analysis used the following estimates of the direct cost for gynecologic care. These values were obtained from Deane and Ulene (24).

Cost of elective hysterectomy $1,545
Cost of hysterectomy for cervical cancer. *2,400*

Cost of hysterectomy for corpus cancer. 3,200
Annual cost of uncured cervical cancer 800
Annual cost of uncured corpus cancer 800
Annual cost of uterine care premenopause. 20
Annual cost of uterine care postmenopause. 10
Cost of abortion . . . . , ... 645
Cost of therapeutic dilatation and curretage 415
Cost of tubal ligation. 1,100

It is felt that these figures are perhaps lower than the actual values; however, the reduction appears to be uniform. In addition to the above cost for medical care, it was assumed that a woman incurs a $10,000 expense during the last months of her life. This expense represents the "cost of dying" but not the "cost of death" (i. e., the value of life) which would be considerably larger.

Basic Result

The analysis estimated the probabilities for death for each year after the initial sterilization procedure. The value of these estimates is listed below for every 10th birthday.

Probability of death on selected birthdays

Age on birthday	*Hysterectomy*	*Tubal ligation*
35	0.00111	0.00055
45	0.00221	0.00256
55	0.00519	0.00552
65	0.01099	0.01122
75	0.02411	0.02405
85	0.03322	0.03280
95	0.01799	0.01766

Notice that the woman sterilized by hysterectomy is more likely than the woman undergoing tubal ligation to die at the time of the procedure (age 35). This increase in operative deaths corresponds to a slight improvement in subsequent survival in that the age at death is shifted to the later years. For example, the probability of death at age 75 is approximately the same for both procedures. On the other hand, death at age 95 is more likely when the woman undergoes hysterectomy. Thus, overall, the life expectancy is 81.3 years, as opposed to 81.0 years with tubal ligation.

The probability for different ranges of total expected costs is listed below. Future costs were discounted at 2 percent per year.

Probability distribution for direct cost
(2-percent discount rate)

Range	*Hysterectomy*	*Tubal ligation*
≤ $5,000	0.158	0.226
≤ 6,000	0.578	0.568
≤ 7,000	0.826	0.806
≤ 8,000	0.921	0.913
≤ 9,000	0.965	0.958
≤ 10,000	0.986	0.982
≤ 11,000	0.996	0.994
≤ 12,000	1.000	0.997
≤ 13,000	1.000	0.998
≤ 18,000	1.000	1.000

The expected direct costs are $6,048 and $6,052 for hysterectomy and tubal ligation, respectively. Although the difference is not large, the higher average cost is associated with tubal ligation because of the chance of expensive cancer therapy and early death.