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MEDICAL GRAND GROUNDS

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THE RISK OF NONCARDIAC SURGERY IN CARDIAC PATIENTS

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"Operating on someone who has no place else to go."

John Kirklin

CONTENTS

INTRODUCTION

An estimate has been made that 38% of all surgical patients over 35 years of age have evidence of heart disease, hypertension or diabetes mellitus. Physicians are frequently asked to estimate the capacity of patients with cardiac disease to undergo surgery. Unfortunately, actuarial tables are not available which define the risk of the type of operation and the cardiac status of patients; therefore, judgment must be somewhat intuitive.

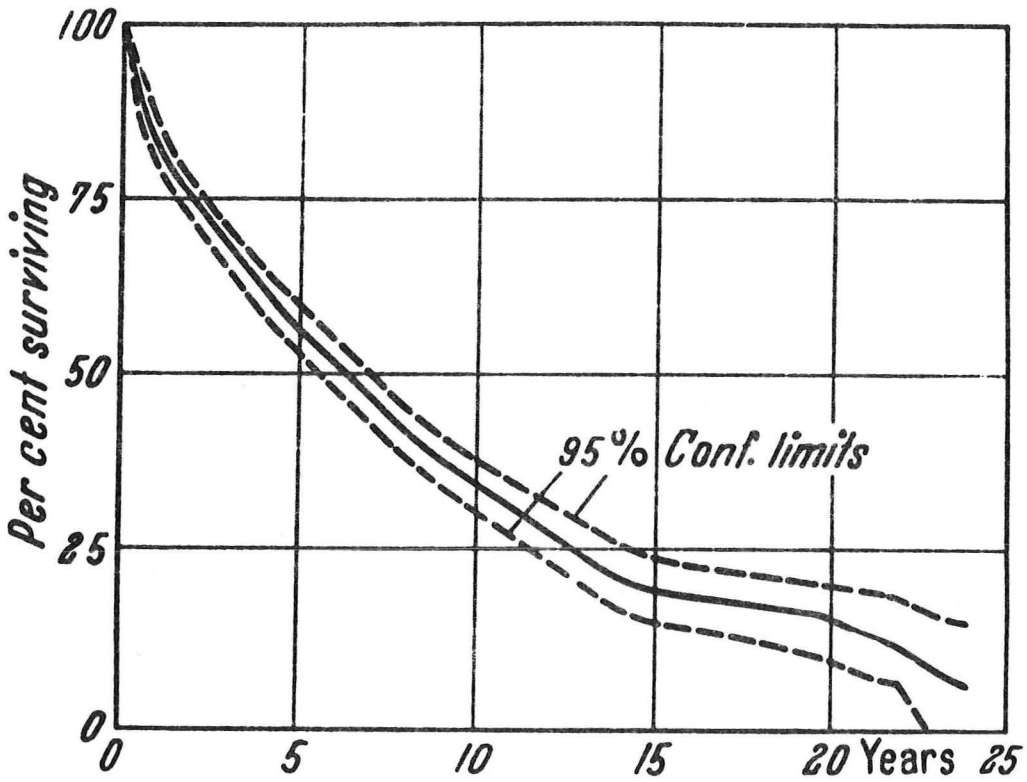
In this protocol I will attempt to review the literature and summarize the data available at this time, keeping in mind the apparent change in incidence of various types of heart disease over the past two decades, the improvement in surgical and anesthetic techniques, and the advancing age of the patients. One must keep in mind when reviewing this protocol that morbidity and mortality statistics may be applied to groups but are less applicable to individuals.

In order to place this review in perspective, it seems appropriate to briefly touch on the mortality in patients with arteriosclerotic heart disease and myocardial infarction unrelated to surgical procedures, especially since the largest section of this review deals with patients with arteriosclerotic heart disease.

LONGEVITY FOLLOWING MYOCARDIAL INFARCTION

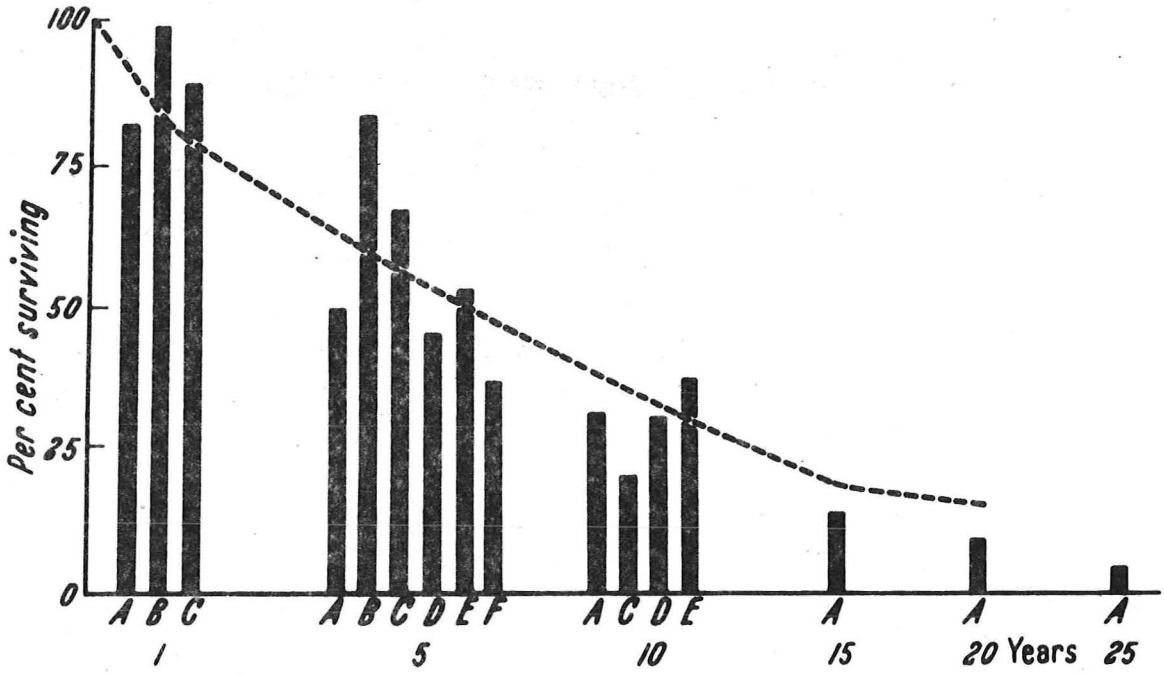
A number of reviews have been published delineating the attrition following myocardial infarction. Pertinent reports to this protocol address themselves to long-term survival beginning one month following the first myocardial infarction since, as we shall see later in this protocol, only emergency surgery should be performed immediately after an acute myocardial infarction.

One of the better reported series and reviews of long-term follow-up of patients with acute myocardial infarction is by Doctor Gunnar Blomqvist (1, 2). He and his associates reported a 20-year follow-up on 1,612 patients in Sweden after an acute myocardial infarction. Their results are plotted in the table below.



Total material, based on 5,216 person years

The percentage surviving after 1, 2, 5, 10, 20 and 24 years is 81.0, 74.5, 55.8, 34.1, 15.2 and 6.1 respectively. These findings are similar to many other series reported in the literature, as seen in the following composite graph.



Comparison with other series. A = White et al. (1956) (8), B = Morris et al. (1952)(9), C = Smith (1953)(10), D = Billings et al. (1949)(11), E = Weiss (1956)(12), F = Eckerstrom (1951)(13). Own material is indicated by the curve.

Mortality following general surgical procedures in postmyocardial infarction patients must be superimposed on this mortality curve in order to clearly define additional surgical mortality over and above the expected attrition rate (i.e., a little > 50% 5 year survival).

GENERAL SURGICAL MORTALITY WITH ARTERIOSCLEROTIC HEART DISEASE (ASHD)

The surgical risk is greater in patients with coronary disease than in other forms of heart disease. The risk is age-related and especially related to the type of operation performed. Even with these factors in consideration, the literature shows wide variations.

A collected series by Nachlas *et al.* (14) and reproduced by Mattingly (15) in the following table show a mortality rate with noncardiac surgery to be 3.4 to 18.2% and a morbidity rate from 4.3 to 24.1%. The combined series of 19,610 operations in noncardiac patients revealed a mortality of 2.9% while 3,144 operations in cardiac patients resulted in a 6.6% mortality and a 10.1% complication rate. This represents more than a two-fold increase in mortality in patients with ASHD.

Comparison of Mortality and Morbidity Rates in Normal and Arteriosclerotic Patients (Collected Series) (14)

			Controls		Cardiac Patients		
Authors	Hospital	Year	Operations (no)	Mortality (%)	Operations (no)	Mortality (%)	Complications (%)
Sprague	Mass. Gen.	1929	-	-	88	18.2*	-
Butler *et al.*	Peter Bent Brigham	1930	-	--	278	5.8†	-
Hickman *et al.* §	Univ. of Chicago	1935	-	-	103	9.7*	12.6‡
Brumm and Willius	Mayo Clinic	1939	-	-	257	4.3*	-
Morrison	New York	1948	9,137	2.8	485	14.8	4.3
Hannigan *et al.*	Memorial (New York)	1951	260	3.4	58	5.2	24.1‡
Lochhead *et al.*	Geo. Wash. University	1954	-	-	51	6.0	6.0
Etsten *et al.* ¶	New England Center	1954	4,154	2.0	1,624	3.4	-
Nachlas *et al.*	Sinai of Baltimore	1959	6,059	3.5	200	10.5	19
Combined Series	--	--	19,610	2.9	3,144	6.6	10.1

*Some authors indicated cardiac deaths only in their mortality figures.

†These authors separated their deaths into expected and unexpected groups, rather than cardiac and noncardiac. Their mortality rate includes only the expected deaths.

‡These authors listed only the cardiorespiratory complications.

§The data from Hickman and associates comprise all cases listed as myocardial disease, coronary thrombosis and angina pectoris. Both major and minor operative procedures were included although there were only a small number of the latter.

¶The comparatively low mortality among the cardiac patients of this series may be due to the fact that only 60 per cent of the operations were considered major procedures.

Mortality with surgical procedures in cardiac patients is definitely related to patient age, as might be expected. In a review of the literature, the following mortality was evident in patients with heart disease.

Mortality Rates in Surgical Patients Over 70

Collected Series

Authors	Cases (no.)	Mortality (%)
Welch (1948)	609	10.2
Childs and Mason (1949)	99	17.2
Bosch *et al.* (1952)	159	17
Owen and Murphy (1952)	434	27.2
Anglem and Bradford (1953)	621	10
Stewart and Alfano (1954)	290	13
Mithoefer and Mithoefer (1954)	240	8.3
Parsons *et al.* (1956)	146	8.2
Limbosch (1956)	336	20.5
Nachlas *et al.* (1961)	77	14.3
Krieger Lassen (1962)	1,197	15.9
Mitty and Echemendia (1963)	589	11.9
Arkins *et al.* (1963)	605	10.8
Totals	5,402	14.1

Mortality Rates in Surgical Patients Over 60

Collected Series

Authors	Cases (no.)	Mortality (%)
Estes (1949	400	6.5
Parsons *et al.* (1949)	322	9.4
Bosch *et al.* (1952)	500	9.6
Haug and Dale (1952)	354	9.0
Cole (1953)	1.099	5.1
Totals	2,675	7.2

Another series reported by Skinner and Pearce (16) divided into decades revealed a similar mortality relationship with age.

Age Related Mortality

Age	total No. of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
<55	87	9.2	35	30
55-64	296	10.8	99	21.2
65-74	244	15.6	90	31.2
75+	139	18	44	27.3

From this data the following summary may be extracted of over-all mortality associated with a variety of surgical lesions and its relationship to patient age (14-24).

*Operative Risk with ASHD**

Patients	Operations	Mortality (%)
All ages - No ASHD	19,610	2.9
All ages - ASHD	3,144	6.6
>60 ASHD	2,675	7.2
>70 ASHD	2,852	14.1

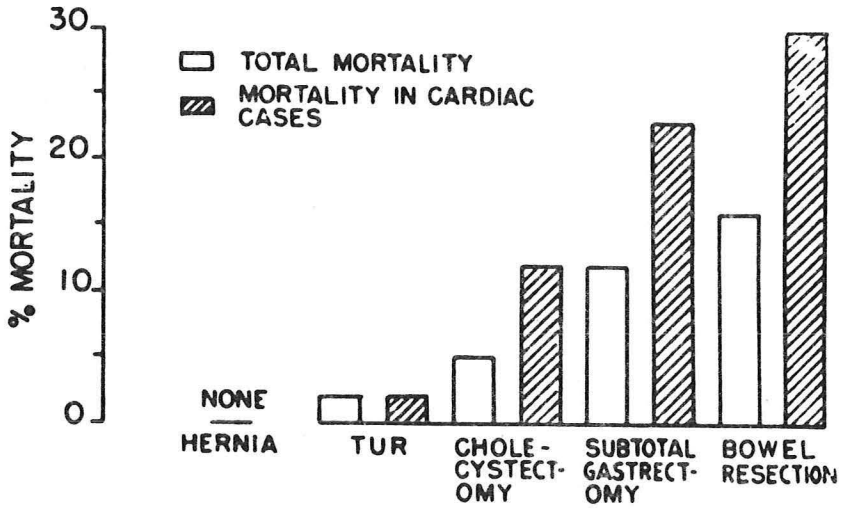
*Review of literature (previous MI or angina [similar]).

INFLUENCE OF THE TYPE OF SURGICAL PROCEDURES ON MORTALITY

The surgical procedure undertaken certainly influences the risk factors, i.e., a herniorrhaphy is much less of a surgical procedure than a gastric resection. The following two tables from Skinner and Pearce (16) illustrate the risk with various operations.

Comparison of Surgical Factors on Mortality in Cardiac Cases (16)

Service performing surgery and type of operation	Total Cases	Mort. (%)	Elective Procedures		Emergency Procedures	
			Cases	Mort. (%)	Cases	Mort. (%)
Ophthalmology	27	0				
Head and neck	14	0				
Proctology	13	0				
Neurosurgery other than craniotomy	14	0				
Neurosurgery, craniotomy	6	50				
Urology						
Transurethral Resection	124	2				
Other	96	12				
General Surgery						
Hernia (inguinal)	80	0				
Cholecystectomy, with and without bile duct exploration	48	12	41	10	7	29
Subtotal gastric resection	48	23	33	18	15	33
Small and large bowel resection	27	30	17	18	10	50
Other intraperitoneal surgery	109	29	73	21	36	47
Misc. general surgical procedures not included above	93	10				
Thoracic surgery						
Intrathoracic procedures	36	30	34	32	2	0
Orthopedic surgery						
Hip nailing	11	36				
Other orthopedic surgery	18	22				



A comparison of surgical mortality in cardiac cases with total surgical mortality in five selected operations.

Alexander and McAlpine (25) reviewed their mortality with cholecystectomy in 100 consecutive cases with heart disease in 1966 and found a mortality of 10% as compared with 1% in the non-cardiac cases. Keys *et al.* (26) evaluated 5,891 patients with cholecystectomy and found an over-all mortality of 0.9% in non-cardiac patients and 3% in their cardiac patients.

Erlik *et al.* (27) have reported a mortality with prostatectomies in 539 patients without cardiovascular disease to be .74% and in 131 patients with cariovascular disease to be .76%, an amazingly low mortality rate with no significant difference in patients with heart disease.

Skinner and Pearce (16) concluded that:

"The above tables document several clinical impressions. . . Transurethral resection (TUR) and inguinal herniorrhaphy have been found to be relatively safe for cardiac patients. Mortality following TUR was 2 per cent and there were no

fatalities following 80 inguinal herniorrhaphies although all of these patients had symptomatic heart disease. Also, sub-specialties such as ophthalmology, head and neck, proctology, and neurosurgery (excluding craniotomies) have low surgical mortalities.

"Of interest was the high mortality associated with intra-peritoneal and intrathoracic surgery. . . . Elective intra-abdominal surgery other than cholecystectomy resulted in a mortality of approximately 20 per cent. Elective cholecystectomy had a significantly lower mortality (10 per cent). Elective intrathoracic surgery exclusive of cardiac surgery was followed by a 32 per cent mortality. Mortality following genito-urinary surgery other than TUR was 12 per cent. Most of these procedures were suprapubic, retropubic, and perineal prostatectomies.

"Mortality following orthopedic surgery was surprisingly high in these cardiac patients. This could be partially explained by the high percentage of patients with Class III functional capacity and by a higher percentage of severely debilitated patients as compared to the entire series. General surgical procedures other than intra-abdominal procedures or herni-orrhaphy were followed by a rather high mortality (10 per cent), but this group was heterogeneous and included many extensive operations."

One must remember that patient selection plays a major role in the above-reported statistics, i.e., patients with severe cardiac disease were rejected for elective operations. This is a major factor in the doubled mortality with emergency operations when compared with the same elective procedure in the table above from Skinner and Pearce (16)(Page 10).

A generality can be made from the data in the literature. The operative risk in cardiac patients is two to three times that of the noncardiac patient when applied to the risk factor for the selected procedure.

DURATION OF OPERATION

The duration of the surgical procedure contributes to the risk factor in all patients, but especially in those with heart disease. An analysis of duration of surgery related to surgical mortality is seen in the following table (16).

Relationship of Duration of Surgery to Mortality in Cardiac Cases

Length of Surgery	No. of Cases	Mortality (%)
Under 1	196	8
1 hr - 1 hr 59 min	314	11
2 hr - 2 hr 59 min	130	17
Over 3 hr	126	23

The above findings indicate that mortality increases with duration of surgery; however, when each operative procedure was compared with itself, a negative correlation was found. (See table below)(16)

Effect of Duration of Surgery on Mortality in Selected Operations in Cardiac Cases

Length of Surgery (Hr)	No. of Cases	Mortality (%)
	Gall bladder surgery	
<2	22	18
>2	26	8
	Subtotal gastric resection	
<3	19	26
>3	29	21
	Bowel resection	
<3	12	42
>3	15	20
	Transurethral resection	
<1	34	6
>1	90	1

Thus, the risk is related to the procedure and not necessarily to the length of the operation. These findings were substantiated in the series reported by Nachlas *et al.* (14).

TYPE OF ANESTHESIA

The choice of anesthetic agents and the route of administration in cardiac patients has been evaluated by several reviewers. The following table is representative of the findings (14).

Relation of Anesthetic Agent and Duration of Operation to Surgical Risk in Cardiac Patients

Category	Operations (no.)	Mortality (%)	Complications (%)
Inhalation anesthesia	115	9.6	22.6
Spinal anesthesia	69	10.1	17.4
Miscellaneous*	16	18.8	0

*The miscellaneous anesthetics included nine local infiltrations, five with combinations of agents and two with the hibernation technic. The more serious nature of the illnesses in these patients is probably responsible for the higher mortality rate.

No correlation between the type of anesthetic agent and the mortality can be found; therefore, no rationale exists for recommending spinal anesthesia (also often true of local anesthesia) in cardiac patients. The expertise of the anesthesiologists is perhaps the most important factor.

Anesthesia for oral surgery is somewhat unique in that epinephrine is frequently used to control the rate of anesthetic agent absorption and dissipation in the tissues and to decrease local hemorrhage. The danger of adrenalin in the cardiac patient, especially the patient with ASHD and angina is evident. However, this danger apparently is minimal since only small amounts are injected, the rate of absorption is slow, and the cardiovascular response is minimal (29-35).

RISK WITH PREVIOUS MYOCARDIAL INFARCTION OR ANGINA

The risk of operation in patients with a previous myocardial infarction or angina is of interest. Skinner and Pearce in the table below correlated mortality with angina and/or a previous myocardial infarction (16).

Effect of Arteriosclerotic and/or Hypertensive Heart Disease on Mortality

	Total No. of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
All cases with angina pectoris	192	11	64	27
Angina with possible or definite hypertensive heart disease	70	9	20	25
All cases of healed myocardial infarction	170	14	70	23
Healed myocardial infarction with possible or definite hypertensive heart disease	45	18	13	31
Angina and healed myocardial infarction	61	16	22	27
Unstable angina	20	10	6	33
Acute myocardial infarction (less than 3 months)	10	40	4	25

A review of the literature in the table below also reveals similar findings. Most importantly is the equal surgical mortality in patients manifesting their ASHD as a previous myocardial infarction (> 3 months postmyocardial infarction) or angina (about 10%). This clearly illustrates that the signs or symptoms are less important; instead, it is the basic disease process (coronary artery disease) which dictates the outcome (14). The yearly mortality in patients with angina is about 15% the first year after onset and 5-10%/year thereafter. This attrition rate is not a great deal different from the mortality with surgery in similar patients.

Relation of the Type of Cardiac Manifestation to the Operative Mortality and Morbidity in Patients With ASHD

Cardiac Abnormality	Authors	Operations (no.)	Mortality (%)	Complications (%)
Angina pectoris	Sprague	13	30.8	-
	Butler *et al.*	41	7.7	-
	Hickman *et al.*	3	33.3	33.3
	Morrison	58	8.6	1.7
	Lochhead *et al.*	21	0	9.5
	Nachlas *et al.*	41	12.2	10.5
	Combined Series	177	10.2	9.8
Myocardial infarction	Butler *et al.*	8	12.5	-
	Hickman *et al.*	8	12.5	50
	Morrison	37	8.1	2.7
	Hannigan *et al.*	58	5.2	24.1
	Lochhead *et al.*	30	10	3.3
	Nachlas *et al.*	52	13.5	32.7
	Combined Series	193	9.3	20

In the table below is a review of the large series in the literature comparing myocardial infarction rates postoperatively with and without previous myocardial infarction (17-18, 38).

Incidence of Postoperative Myocardial Infarction

	Operations	Postop Coronary Occlusion (# Pts)	(%)
No previous MI			
Knapp	8,557	59	.7
Tarhan	32,455	43	.13
Topkins	12,054	79	.66
Previous MI			
Knapp	427	26	6
Tarhan	422	28	6.6
Topkins	658	43	6.5

This large series indicate a 10 to 20-fold increase in postop myocardial infarction in patients with a previous myocardial infarction.

Other reports are less well documented but show some variation in this figure of .7 and 6% postoperative infarction rate without and with ASHD respectively. Hunter *et al.* (39) have found a 2% incidence of infarction in a mixed group of patients. Baer *et al.* (40) in a similar group reported a 10% incidence postoperative infarction.

Mauney *et al.* (41) reported in 365 patients, over the age of 50 with abnormal ECG changes preoperatively, an 8% postoperative infarction rate with a 53% mortality. The ECG changes preoperatively included one or more of the following: 1) previous myocardial infarction, 2) bundle branch block, 3) left ventricular hypertrophy or strain, and 4) ST changes of injury. This group is a readily identifiable group of high risk patients.

HYPOTENSION

Even more significant was the relationship of hypotension in the group of patients shown in the table below (41).

Distribution of 118 Patients Having a 30 Per Cent Decrease in Systolic Blood Pressure Sustained a 10-Minute or Longer Period During Operation

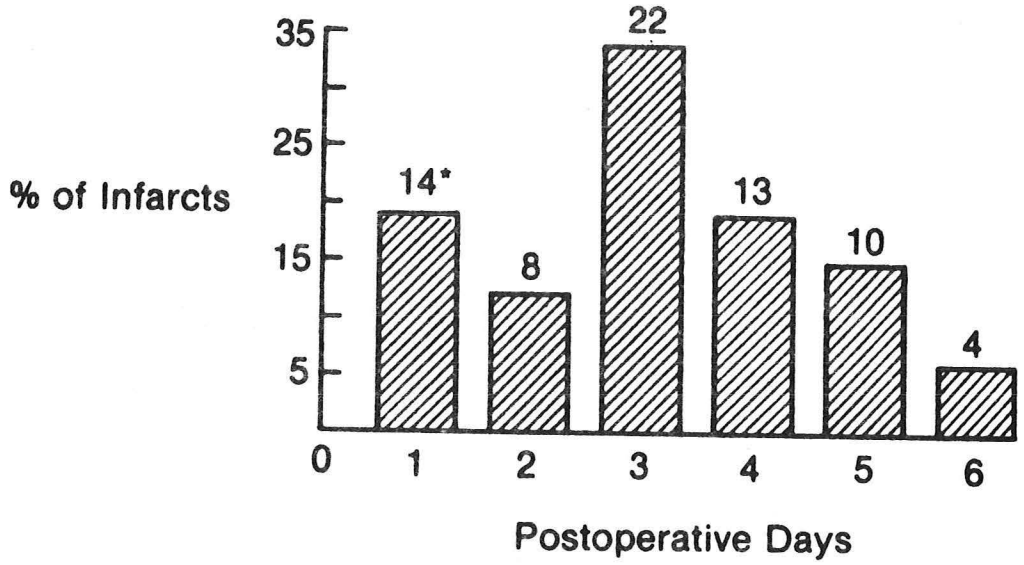
Group	No. in Group	No. with BP Decrease	Per Cent of Group	Average Decrease mm Hg
No postoperative ECG change	301	87	29	60
Postoperative ECG evidence of ischemia	34	13	38	61
Postoperative MI survivors	14	8	58	64
Postoperative MI died	16	10	62	66
Total	365	118		

Fifteen per cent of patients with this magnitude of intraoperative hypotension developed postoperative myocardial infarction compared with 3.5% in the nonhypotensive group. This represents a 4-fold increase in myocardial infarction rate. Nachlas and co-workers (14) reported similar findings of 11.5% mortality in high risk patients becoming hypotensive during operation as compared to an 8.5% mortality when no

operative hypotension occurred.

One cannot with certainty attribute hypotension to the development of an acute intraoperative myocardial infarction since the hypotension may be the result rather than the cause of the MI. However, it seems prudent, with our knowledge of coronary perfusion and its relationship to mean aortic pressure, to guard against significant declines in blood pressure in patients with coronary artery disease.

Of interest is the time of occurrence of myocardial infarction in the operative and postoperative period (38).



*Distribution of myocardial infarctions by postoperative days. *Number of patients.*

These findings emphasize the need for serial postoperative ECG's and enzymes in high risk patients to detect late infarctions.

The relationship of site of operation and incidence of myocardial infarction is shown below (38).

Relation of Myocardial Infarction to Site and Type of Operation

Site and Type of Operation	Previously	Again, Post-operatively	Again (%)
Thorax and upper abdomen	(131)	(16)	(12.2)*
Great vessels	54	5	9.9
Lung	14	5	36.0
Other intrathoracic	4	3	75.0
Biliary, upper abdomen	59	3	5.0
Other	(291)	(12)	(4.1)*
Extraperitoneal abdominal	7	1	14.0
Endoscopic: oral	8	2	25.0
perineal	5	2	40.0
Perineal GU†	48	2	4.0
Anorectal	7	1	14.0
Vertebral column	16	1	6.0
Extremities, bone	23	2	9.0
Head and neck	18	1	6.0
Miscellaneous	159	-	-
Total	422	m 28	6.6

*Difference between groups is significant ($p < .001$).
†Genitourinary

Several factors may precipitate myocardial infarction during and after operation: tachycardia, hypoxemia, hypotension, hemorrhage, and lowered cardiac output. These complications are more frequent after surgery of the great vessels, lung, and the upper abdomen. As a group, these more-major kinds of operations are followed by three times as many infarctions as any other type of operation. This fact indicates the need for close attention to maintaining optimal blood volume and pressure in the postoperative period.

MORTALITY WITH POSTOPERATIVE MYOCARDIAL INFARCTION

The mortality in the postoperative period related to the myocardial infarction is striking ((18). This represents a 3-fold increase in mortality.

Mortality From Postoperative Myocardial Infarction

	Total No. of Cases	Postop MI	Mortality
No preoperative history of myocardial infarction	12,054	79(.66%)	21(26.5%)
Positive preoperative history of myocardial infarction	658	43(6.5%)	31(70.0%)
Totals	12,712	122	52(42.0%)

Arkins (42) correlated preoperative coronary pathology with postoperative myocardial infarction and found the following:

Mortality in Relation to Preoperative Coronary Pathology

Preoperative Coronary Pathology	Patients No.	Deaths No.	(%)
Recent myocardial infarction			
Transmural	13	10	77
Subendocardial	14	1	7
Old myocardial infarction	240	54	22.6
Other pathology	730	160	21.5
Totals	1,005	225	22

These findings suggest that recent transmural myocardial infarction carries a prohibitive operative risk (< 3 months), while a subendocardial myocardial infarction is more benign.

Mortality associated with postoperative myocardial infarction is variable but generally significantly higher than the anticipated mortality from myocardial infarction unrelated to surgical procedure (15, 17, 38-43).

Mortality in Relation to Postoperative Myocardial Infarction

Authors	Patients No.	Deaths No.	(%)
DePeyster *et al.*	10	7	70
Wrobienski *et al.*	15	6	40
Wasserman *et al.*	25	5	20
Etsten *et al.*	11	2	18
Knapp *et al.*	26	15	58
Master *et al.*	35	23	66
Arkins *et al.*	55	38	69
Mauney *et al.*	30	16	53
Tarhan *et al.*	28	15	54
Totals	235	127	54

By comparison, the mortality from myocardial infarction in a general hospital is approximately 30%, and in a coronary care unit this may be reduced to 15-20%. So myocardial infarction, or recurrent infarction, after anesthesia and a major operation, is more serious and lethal than myocardial infarction alone.

AGE OF MYOCARDIAL INFARCTION AND MORTALITY

The relationship of the age of the myocardial infarction prior to surgery and a new postoperative myocardial infarction is important to decide when elective and semielective operative procedures could be accomplished with minimal risk (17-18).

Effect of Time Interval Between Coronary Occlusion and Operation on Incidence of Postoperative Occlusion in Men Over 50 With Preoperative Coronary Occlusion and/or MI

Time Interval	Patients With Preoperative Coronary Occlusions*	Patients With Postoperative Coronary Occlusions*	Patients With Preoperative Myocardial Infarction†	Patients With Postoperative Myocardial Infarction†
< 6 mos.	7	7(100%)	22	12(54.5%)
6 mos.-1 yr.	21	7(33%)	36	9(25.0%)
1 yr. -2 yr.	22	9(41%)	49	11(22.4%)
2 yr. -3 yr.	25	3(12%)	51	3(5.9%)
> 3 yr.	352	0	493	5(1.0%)
Total	427	26	651	40

*Knapp *et al.* (17).
†Topkins *et al.* (18)

Acute Infarcts: Mortality Related to Proximity to Surgery

Infarct to Surgery (Days)	No. of Cases	No. of Mortalities	Mortality (%)
1-15	28	12	43
15-30	15	5	33
30-45	0	0	0
45-60	1	1	100
60-75	1	1	100
75-90	5	0	0
Total	50	19	38

Fraser *et al.* (44) in the above table also evaluated the mortality with surgery in relationship to recent prior myocardial infarction and concluded that the first 15 days postinfarction are the most critical. The notable decline in mortality past the initial 15 days suggests judicious delay in all but the most urgent surgery.

Tarhan (38) also evaluated 422 patients with previous myocardial infarctions undergoing major surgical procedures with relationship to postoperative infarction in the table below.

Relation of Myocardial Infarction to Interval From Previous MI

	Myocardial Infarction		
Months	Previously	Again, Post operatively	Again (%)
0-3	8	3	37
4-6	19	3	16
7-12	42	2	5
13-18	27	1	4
19-24	21	1	5
25+	232	11	5
Old	73	7	10
Total	422	28	6.6

The per cent reinfarction rate was **37%** < 3 months, 16% 3-6 months, and 5% thereafter.

The following table summarizes the findings in the literature regarding early operation in the setting of a myocardial infarction (16-18, 38, 42-45).

*Mortality Related to Interval After MI**

	Interval	Postop MI (No. Pts)	(%)	Mortality (%)
Fraser	<3 Mo.	19/50	38	
Etsten	<2 Mo.	2/11		19
Topkins	<6 Mo.	12/22	55	
Arkins	<3 Mo.			
Transmural		10/13		77
Subendocardial		1/14		7
Total		11/27		46
Knapp	<6 Mo.	7/7	100	
Tarhan	<3 Mo.	3/8	37	
Tarhan	3-6 Mo.	3/10	16	
Baker	<3 Mo.	0/16		
Skinner-Pearce	<3 Mo.	4/10		40
Dana-Ohler	<3 Mo.	2/5		40

*Numbers are small

In summary, this data suggests that surgical risks become prohibitive within the first 3 months of an acute transmural myocardial infarction unless the surgery is for a life-threatening situation.

It is generally recognized that the healing time of myocardial infarction does not exceed 3 months. The process of healing depends in part upon the size of the infarct and in part upon the condition of the myocardial circulation. Most infarcts may be considered healed after 2 months and undergo little change after that (47). Within an additional third month the healing process should be consolidated.

There seems to be little evidence that mortality and morbidity from surgical procedures in patients postmyocardial infarction should be significantly increased after 3 months postmyocardial infarction over and above the expected morbidity and mortality occurring during this same period in patients postmyocardial infarction not undergoing surgical procedures (postmyocardial infarction attrition rate).

To summarize the risk of surgery in patients > 50 years of age:

Risk of Surgery (> 50 Y/O)

A. No previous ASHD

0.7-1% MI

19-40% Mortality with MI

3% = Over-all Surgical Mortality

B. Previous ASHD

4-6.5% MI

40-70% Mortality with MI

6-10% = Over-all Surgical Mortality

Generally, Risk with ASHD = 2-3 Times > Without ASHD

The reports in the literature of postoperative incidence of mortality from myocardial infarction are precoronary care units and preanesthetic and surgical monitoring in the operating and recover rooms. Arrhythmias are now detected immediately with monitoring systems and with highly trained teams the mortality from arrhythmias associated with acute infarction is minimal. Knowledge of the pathophysiology of myocardial infarctions has lead to a highly sophisticated approach to the prevention of hypotension, hypertension, tachycardia and severe bradycardia during anesthesia and in the recovery period. For these reasons the incidence of myocardial infarction in cardiac patients undergoing surgical procedures now should be considerably less than in these earlier reports. For instance, the mortality from coronary surgery with heart-lung bypass in patients with severe coronary artery disease approaches 10%, a truly remarkable result.

ENZYMES

Difficulties inherent in utilizing enzyme studies to diagnose myocardial muscle necrosis in surgical patients are well known. A wide latitude of variation occurs due to varying degrees of skeletal muscle and liver trauma. Isoenzymes may be helpful but not always diagnostic of myocardial injury.

SGOT

Ayres and Willard (48) measured SGOT changes in 266 operations with no evidence of myocardial damage. They found 20% of these patients demonstrating elevations of their SGOT. Their results are summarized in the following table.

Incidence of SGOT Elevation in Various Operations

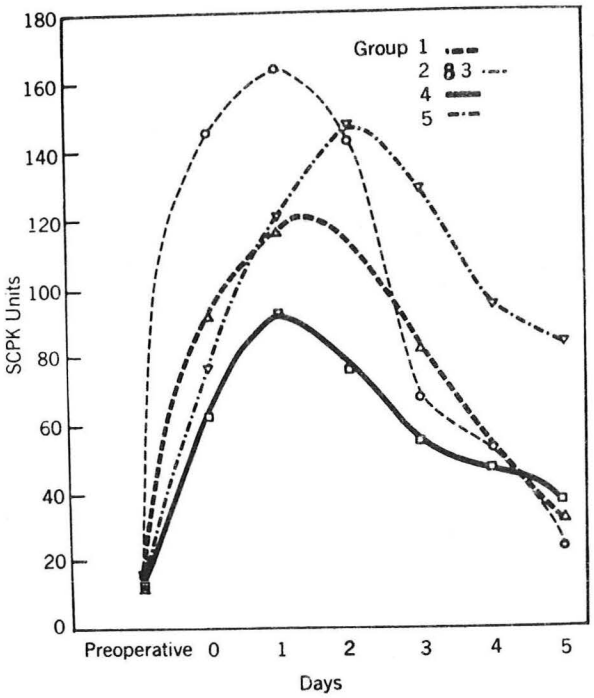
Operation	Total	No. With SGOT Elevation
Cholecystectomy, simple	36	17
Cholecystectomy with common duct exploration	13	13
Abdominal (except biliary)	42	5
Abdominoperineal resection	7	1
Pelvic	52	3
Genitourinary	29	4
Thoracic	14	3
Orthopedic	53	4
Neurologic (craniotomy)	5	2
Mastectomy	6	1
Miscellaneous	9	1
Totals	266	54

Most of these elevations were low level, < 100. The majority of elevations occurred with biliary tract operations. These results suggest that the SGOT may be of value in most operations as an aid to diagnosis of myocardial infarction. However, enough variables occur to make the SGOT alone a tenuous diagnostic tool. It is of no value in biliary tract surgery. These results are similar to those reported by Kelley *et al.* (49).

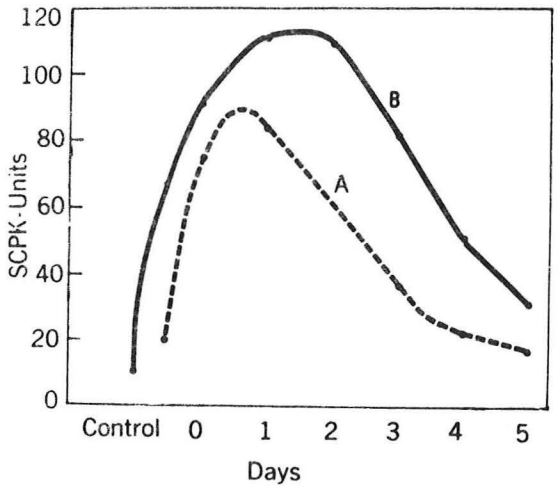
CPK

Determination of the activity of serum creatinine phosphokinase (CPK) has proved extremely useful in the diagnosis and verification of AMI occurring in nonsurgical patients. The highest concentrations of this enzyme are in skeletal muscle, myocardium, and brain: little activity is present in red blood cells or liver. In addition to myocardial infarction, an increase in CPK activity can be caused by skeletal muscle trauma, myopathies, hypothyroidism, and cerebral disorders.

The use of this enzyme in evaluating patients for a recent MI is of less value following surgery because of skeletal muscle damage. A study by Dixon *et al.* (51) in 58 noncardiac operations has shown the following results:



—Serum creatine phosphokinase plotted as mean values for each group. Group 1, thoracotomy; groups 2 and 3, open- and closed-heart operations; group 4, laparotomy; group 5, patients with postoperative AMI. There is no statistical difference between groups at any time interval.



—Comparison between mean SCPK activity in 33 nonsurgical patients (A) with AMI, and 24 postoperative patients having thoracotomy without cardiac manipulation or AMI (B). Control value for B is the mean preoperative SCPK activity. The control for A is the mean SCPK obtained upon hospital admission. Therefore, temporal sequence of SCPK change is not strictly comparable.

Similar findings have been reported by Cattolica (50) in 37 patients undergoing transurethral prostatectomy (TUR). The elvation in CPK in these patients is thought to be due to damage to the detrusor smooth muscle.

These results indicate the uselessness of this enzyme to determine postoperative myocardial infarction. Isoenzymes, if available, may be more valuable since this determination will permit differentiation of myocardial CPK from other cellular origins of the enzyme.

In summary, the SGOT and CPK are of limited value in the diagnosis of postoperative myocardial infarction. The SGOT is the most useful in nonabdominal (especially liver and bile duct) operations while the CPK is of little value. A delayed peak or persistence beyond 48 hours in either or both enzymes may indicate an acute myocardial infarction. The ECG remains the most valid evidence for postoperative myocardial infarction.

MORTALITY AND THE ELECTROCARDIOGRAM

The ECG alone may be a predictor of increased mortality in certain instances. The following review by Skinner and Pearce (16) is representative of this correlation.

The Electrocardiogram and Mortality

	Total No. Of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
Normal ECG	76	7	19	16
Atrial fibrillation	99	13	29	28
1st degree heart block	34	15	15	20
Atrial flutter	4	50	2	50
3rd degree heart block	5	20	2	50
Left bundle branch block	39	23	11	54
Right bundle branch block	38	16	8	37
Intraventricular conduction defect	41	15	16	25

The numbers are too few for a valid statistical analysis. However, the patients with normal ECG's did better than those with abnormal ECG's. Conduction disturbances and arrhythmias (especially atrial flutter) had a higher mortality than the remainder of the group. Left bundle branch block was followed by a 23% mortality as compared with 7% in patients with normal ECG's.

Gertler *et al.* (54) reported 15 patients with right bundle branch block and 6 with left bundle branch block with no surgical mortality. Pfeiffer and LaDue (55) and Berg and Kotler (56) also showed no increased mortality with conduction defects.

No conclusion can be derived at this time regarding the significance of conduction defects and mortality with noncardiac surgery. The indications for temporary cardiac pacing during surgery are also difficult to define.

CONGESTIVE HEART FAILURE

Every effort should be made to treat and overcome congestive heart failure prior to operation. Only life-threatening emergency operations should be performed in uncomplicated patients. The mortality rate with surgery rapidly increases as the functional classification (I-IV) increases.

Care should be taken not to overdiurese patients and decrease their cardiac output and cardiac reserve. Anesthetics may decrease peripheral vascular resistance and vasovagal reactions may occur,

resulting in hypotension in cardiac patients. Patients with depressed cardiac outputs due to overdiuresis are especially prone to become hypotensive.

Antihypertensive drugs may also result in hypotension during anesthesia. These drugs, including diuretics, should be discontinued, if possible, prior to surgery. The anesthesiologist should be aware the patient has been taking the drugs so that he may anticipate hypotension and have appropriate drugs readily available to maintain blood pressure. Additional saline infusions may be indicated prior to or during induction in those patients thought to be volume depleted or peripherally dilated.

FUNCTIONAL CLASSIFICATION (DEBILITY) AND SURGICAL RISK

The functional classification (NYHA) of cardiac patients is clearly related to the degree of cardiac dysfunction, and this is reflected in the surgical mortality (16).

Relationship of Functional Classification to Mortality

Functional classification*	Total No. of Cases	Mortality (%)
Class I	46	4
Class II	569	11
Class III	145	25
Class IV	6	67

*New York Heart Association

Furthermore, the risk of surgery increases in each functional class if the patient requires digitalis and diuretics to maintain the functional classification, as suggested from the table below (16).

Effect of Digitalis and Diuretics

Functional classification*	Total No. of Cases	Mortality (%)
Class II (No digitalis or diuretics)	325	9
Class II (Digitalis and/or diuretics)	244	12
Class III (No digitalis or diuretics)	16	19
Class III (Digitalis and/or diuretics)	109	27

*New York Heart Association

RHEUMATIC VALVULAR HEART DISEASE

The mortality and morbidity in this group of patients are clearly tied to the functional classification, i.e., the magnitude of their congestive heart failure.

Skinner and Pearce (16) found the following results in noncardiac surgery in their patients with valvular heart disease maximally compensated prior to surgery.

Mortality in Rheumatic Heart Disease

Type Of Heart Disease	Total No. Of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
Mitral lesion	35	6	9	6
Aortic lesion	59	10	15	20
Combined lesion	17	6	4	25

Patients with valvular heart disease tolerate surgery better than patients with arteriosclerotic heart disease. Morrison (23) noted a 4.8% mortality in 108 patients with mitral valve disease undergoing 147 procedures and concluded that there was only a slight increase in surgical risk in this group. Aortic valve disease, especially stenosis, has the worst prognosis of all the valvular diseases.

HYPERTENSION

The risk of elevated blood pressure to surgical mortality was evaluated by several authors. Surprisingly, no real increase in mortality resulted in the hypertensive patients. Perhaps this was, in part, patient selection. Furthermore, patients undergoing treatment with antihypertensive agents had very little increased risk of operation or anesthesia (16, 28, 36-37).

Blood Pressure and Mortality in Cardiac Cases (16)

Blood Pressure (mm Hg)	Total No. Of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
Systolic				
<100	12	50	9	55
101-140	368	11	146	23
141-200	331	14	96	25
>200	55	14	17	29
Diastolic				
<51	13	15	6	33
51-95	562	12	195	24
96-110	148	17	45	31
>110	43	16	22	27

ASSOCIATED PULMONARY DISEASE

Skinner and Pearce (16) evaluated 75 cases with acquired heart disease and co-existent symptomatic chronic lung disease without definite evidence of cor pulmonale and 25 cases of cor pulmonale. Their results are:

Mortality in Functionally Symptomatic Chronic Pulmonary Disease With and Without Cor Pulmonale

	Total No. Of Cases	Mortality (%)	Intrathoracic and Intra-abdominal	
			Cases	Mortality (%)
Chronic pulmonary without cor pulmonale	75	20	27	37
Pulmonary heart disease	24	29	12	50

In summary, one might formulate the following risk scale for non-cardiac operations in cardiac patients:

Order of Increasing Surgical Risks

No cardiac disease
Hypertension
Angina infrequent with normal ECG
Angina frequent
Angina infrequent with abnormal ECG
Previous MI, asymptomatic < 2 years
Previous MI, symptomatic
Other heart disease - Functional Class III and IV
Associated severe pulmonary disease
Recent MI < 3 months

INDICATIONS FOR PROPHYLACTIC DEMAND PACING PRIOR TO ANESTHESIA AND OPERATION

A temporary demand transvenous-type pacemaker is probably indicated in the following situations: 1) second-degree atrioventricular (AV) block, 2) third degree AV block, 3) right bundle branch block with abnormal right or left axis deviation and first degree AV block, 4) left bundle branch block and first degree AV block, 5) alternating right bundle branch block and left bundle branch block, 6) sinoatrial block, and 7) a history of Adams-Stokes seizures. The pacing catheter should not be removed until after the patient's conditions has been stable for several days. We are currently using the above indications for pacing; however, exception has been taken to these indications. Berg and Kotler (56) report the following:

> "Thirty patients with electrocardiographic evidence of bilateral bundle branch block (BBBB) underwent 36 surgical procedures. Despite an 83 per cent incidence of significant cardiac disease, the overall mortality was 10 per cent. In no case was death attributable to complete heart block, though one patient was found at postmortem to have suffered acute myocardial infarction. Patients with previous syncopal episodes showed no increased incidence of arrhythmias and no patient had a documented Stokes-Adams attack. It would appear that the routine use of temporary cardiac pacemakers is not justified in the preoperative patient with presumed BBBB. However, since the factors that ultimately cause complete heart block are not known in patients with BBBB, constant cardiac monitoring is mandatory in the intraoperative and immediate postoperative period."

PROPHYLACTIC DIGITALIZATION

In the absence of overt heart failure or atrial flutter or fibrillation the prophylactic administration of digitalis in the preparation of patients for anesthesia and operation remains controversial. Routine digitalization of all elderly patients prior to major surgery has been advocated by some (58), whereas others believe that digitalis is not indicated even in patients about to undergo cardiac surgery (59).

Unexpected acute heart failure and/or serious cardiac arrhythmias during or after major surgical procedures were first described by Levine (60) in 1920. Since then, numerous reports have dealt with the effects of digitalis on the prevention and management of these problems during anesthesia, operation and the postoperative period (61-63).

Effects of Anesthesia on Cardiovascular Function

All general anesthetics depress contractility of the isolated heart or decrease cardiac output of the heart-lung preparation at concentrations which produce light surgical anesthesia (64-65). In normal man receiving ether or cyclopropane, cardiac output is well maintained or, in some instances, increased until deep planes of anesthesia are reached. Increased sympathetic activity during ether or cyclopropane anesthesia, as evidenced by increased levels of circulating norepinephrine, may explain, in part, the cardiovascular response in man and animals. Halothane and methoxyflurane, on the other hand, generally result in significant reductions in cardiac output in normal man. In the patient with heart disease with borderline cardiac compensation, induction of anesthesia with any anesthetic may result in significant impairment of cardiac contractility. In general, light cyclopropane and light nitrous oxide anesthesia appear to have the smallest myocardial depressant effects in these patients, although precise measurements of cardiac function have not been reported.

Operation and the Postoperative Period

Following a major abdominal or thoracic operation, there is a substantial rise in cardiac output (66-68) in response to the multiple stresses of operation and the postoperative period. Additional increases in cardiac output may occur in the presence of postoperative complications. Inability to achieve this obligatory increase in cardiac output may result in congestive heart failure of the classical type, or the "low cardiac output syndrome" with low urine output, vasoconstriction and hypotension. Postoperative mortality is higher in patients whose cardiac outputs do not increase in response to these metabolic demands (67-68).

In patients with rheumatic, hypertensive or coronary artery disease without heart failure, cardiac decompensation may occur for the first time in response to anesthesia and operation. In these patients, cardiac function is adequate to maintain compensation during normal activity, but cardiac reserve may be insufficient to allow an increase in cardiac output appropriate to the stress of operation.

Modification by Digitalis of the Cardiac Effects of Anesthesia Operation and Postoperative Stress

Prophylactic administration of digitalis may reduce the negative inotropic effects of anesthetic agents. Goldberg and coworkers demonstrated that digoxin reduces the negative inotropic effects of large doses of thiopental (69) and halothane (70). Shimosato and Etsten (71) observed that ouabain reduces myocardial depression secondary to administration of halothane in dogs.

These studies indicate that in patients with limited cardiac reserve, digitalis given prior to induction of anesthesia may prevent the cardiac depressant effects of anesthesia.

Cardiac Arrhythmias With Anesthesia, Operation and Postoperative Period

In nearly every reported series, atrial fibrillation or flutter has been the arrhythmia noted most frequently in the postoperative period. In a review of the literature by Deutsch and Dalen (72), they found the following incidence of arrhythmias:

Types of Reported Postoperative Arrhythmias (73-78)

	Per Cent of Reported Arrhythmias
Atrial Flutter Atrial Fibrillation	70
AV block Ventricular Tachycardia	12
Atrial Tachycardia Supraventricular Tachycardia Nodal Tachycardia	18

From this data it is apparent that digitalization might be of value in this group of patients.

In patients who are likely to develop postoperative atrial fibrillation or flutter, i.e., the elderly and those with heart disease, preoperative digitalization decreases the probability of rapid ventricular rates. Rapid ventricular response to atrial fibrillation is a threat *per se*, and its therapy may present additional hazards to the patient.

The effect of preoperative digitalization on ventricular rate was studied in 53 patients who developed atrial fibrillation after mitral valve surgery (79). In 12 patients who had not taken digitalis, the average increase in ventricular rate with the onset of atrial fibrillation was 74 beats/min, resulting in an average ventricular rate of 163 (range 120-200). In 18 patients who had been incompletely digitalized, ventricular rate increased by 50 beats/min, with a resultant average ventricular rate of 138. However, in 23 patients who had been fully digitalized prior to surgery, the average increase was only 22 beats/min when atrial fibrillation occurred.

There is some evidence that in addition to slowing ventricular rate if atrial fibrillation or flutter occurs preoperative digitalization may actually decrease the incidence of postoperative arrhythmias. In a series of 302 patients not digitalized before thoracic surgery, the incidence of postoperative arrhythmias was 23 per cent, whereas in 137 digitalized patients, the incidence was only 12 per cent (74). In another series of patients undergoing pulmonary procedures, postoperative arrhythmias occurred in seven of the 50 nondigitalized patients, but in only two of 73 digitalized patients (75).

Another series was reported by McCord (80) of 68 patients undergoing colon and rectal surgery with associated cardiovascular disease and over 60 years of age. Twenty-nine were digitalized and 39 were not digitalized preoperatively. In the digitalized group, a C-V complication rate of 17% and mortality rate of 7% were found while in the group not digitalized, a C-V complication rate of 40% was reported and an 18% mortality.

Brockner and Christiansen (81) have evaluated the cardiac complications requiring digitalization in the postoperative period in a homogenous group of surgical patients.

The incidence of postoperative cardiac complications requring digitalization was studied in 235 patients operated upon for carcinoma of the stomach.

Six patients had atrial fibrillation with rapid perpetual arrhythmia or manifest decompensation. These were the only ones to be digitalized preoperatively; no complications were recorded in 5 of

them, while one succumbed on the sixth postoperative day to coronary occlusion.

Sixty-eight of the remaining patients had either cardiac symptoms in their histories, electrocardiographic changes suggestive of myocardial degeneration, or enlargement of the heart demonstrated roetgenographically. These patients were not digitalized preoperatively; 50 per cent of them developed postoperative cardiac complications requiring digitalization.

Albeit this data is circumstantial, it does suggest some benefit from preoperative digitalization in patients with cardiac disease.

Deutsch and Dalen (72) have formulated the following indications:

Recommendations for Preoperative Digitalization

(in Patients for Whom Digitalis is Not Contraindicated)

I. Established indications
   - A. Overt heart failure
   - B. Atrial fibrillation or flutter

II. Prophylactic digitalization
   - A. To prevent intra- or postoperative heart failure:
     1. Past history of heart failure even though now well compensated
     2. Cardiac enlargement disclosed by chest x-ray
     3. EKG evidence of left or right ventricular hypertrophy
     4. Evidence of coronary artery disease (by history or EKG)
   - B. To prevent or control postoperative arrhythmias:
     1. History of documented episodes of atrial fibrillation or flutter
     2. All patients undergoing cardiac surgery
     3. Patients over age 50 undergoing pulmonary surgery
     4. Patients with aortic stenosis or mitral stenosis (with or without cardiac enlargement)

Perhaps this is overzealous but should be considered and individualized when consulting in the preoperative period.

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