Medical Intelligence

Indications for Prophylactic Digitalization

Stanley Deutsch, Ph.D., M.D.,* and James E. Dalen, M.D.†

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,[1] whereas others believe that digitalis is not indicated even in patients about to undergo cardiac surgery.[2]

Unexpected acute heart failure and/or serious cardiac arrhythmias during or after major surgical procedures were first described by Levine[3] 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.[4, 5, 6]

In this article we review the clinical pharmacology of digitalis, and discuss the factors associated with anesthesia and operation that predispose to heart failure and arrhythmias. On the basis of these considerations, evidence that prophylactic digitalization is indicated in the preparation of certain patients for anesthesia and operation is presented.

Clinical Pharmacology of Digitalis

The cardiac effects of digitalis will be emphasized, although digitalis acts on other areas, including the central nervous system and kidney. Use of digitalis for the treatment of heart

failure is based upon its property of increasing the force of ventricular contraction. This positive inotropic effect has been demonstrated in man in normal[7] as well as in failing hearts.[8] With increase in the force of systole, low cardiac output is increased, and the many effects of heart failure which lead to edema formation and pulmonary congestion are reversed.[9] The exact mechanism by which digitalis increases myocardial contractile force remains to be elucidated, but potentiation of excitation–contraction coupling appears to be the most likely possibility.[10]

Use of digitalis in the management of cardiac arrhythmias is based on its property of slowing heart rate. This slowing is the result of a number of effects. Digitalis has a vagal enhancing effect on the sinoatrial node which slows heart rate. It decreases conduction velocity within atrial and ventricular muscle and the atrioventricular conduction system. This results in slowing of the ventricular response to supraventricular tachycardia, especially atrial flutter and fibrillation. In patients with heart failure, digitalis also reduces heart rate by increasing cardiac output, with a resultant reduction in the compensatory reflex sinus tachycardia associated with high adrenergic tone in heart failure.[9] The electrophysiologic effects of digitalis are believed to be based on active transport mechanisms involved in exchange of sodium and potassium.[10]

Effects of Anesthesia, Operation and the Postoperative Period on Myocardial Function

ANESTHESIA

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.[11, 12] In normal man receiving ether or cyclopropane, cardiac output is well main-

tained or, in some instances, increased until deep planes of anesthesia are reached.[13, 14] 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 [15] 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,[16-18] 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.[17, 18]

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 co-workers demonstrated that digoxin reduces the negative inotropic effects of large doses of thiopental [19]

and halothane.[20] Shimosato and Etsten [21] 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.

There has been reluctance to accept the presence of heart disease *per se* as an indication for preoperative digitalization because of early observations that digitalization of the nonfailing heart does not increase cardiac output. The failure of digitalis to increase cardiac output *when it is already normal* had been taken as evidence that digitalis has no therapeutic effect on the nonfailing heart. Recent investigations,[22, 23] however, have provided abundant evidence that digitalis does indeed have a potent positive inotropic effect on the normal heart. Measurement of myocardial contractility during cardiac surgery using a strain-gauge arch sutured to the right ventricle of the patient with congenital heart disease, without congestive failure, has shown a clear increase in myocardial contractility in response to acute digitalization.[22] Other evidence of the positive inotropic effect of digitalis on the non-failing heart has been obtained during cardiac catheterization of normal patients, in whom acute digitalization increases the rate of rise of intraventricular pressure (dp/dt), indicating enhancement of myocardial contractility.[23] These studies have demonstrated that the positive inotropic effect of digitalis increases cardiac output *only* if cardiac output is low.

Pretreatment with digitalis enhances cardiac function in response to a variety of experimental stresses. In dogs subjected to potassium citrate-induced cardiac arrest, pretreatment with digitalis enhanced recovery of left ventricular function.[24] A similar protective effect of digitalis has been shown in dogs subjected to hypothermia and venous inflow occlusion [25] or massive transfusion in hemorrhagic shock.[26] Administration of digitoxin to rats in which aortic constriction had been performed reduced mortality from cardiac failure and reduced the degree of left ventricular hypertrophy.[27] Comparable studies of the protective value of digitalis in man subjected to various forms of stress are obviously not feasible. However, in a small series of patients

TABLE 1. Types of Reported Postoperative Arrhythmias

	Krosnick and Wasserman[29] (thoracic surgery)	Rogers et al.[34] (general surgery)	Wheat and Burford[30] (thoracic surgery)	Williams et al.[33] (cardiac surgery)	Per Cent of Reported Arrhythmias
Atrial flutter	3	6	—	12	70
Atrial fibrillation	13	19	47	11	
AV block	—	—	—	10	12
Ventricular tachycardia	1	—	—	8	
Atrial tachycardia	—	2	—	—	18
Supraventricular tachycardia	—	12	5	—	
Nodal tachycardia	—	6	—	5	
Total arrhythmias	17	45	52	46	

with heart disease without heart failure, digitalis decreased the oxygen debt associated with exercise.[28]

These investigations indicate that digitalis, by virtue of its positive inotropic effect, facilitates the mandatory increase in cardiac output in response to operation and its potential complications.

Cardiac Arrhythmias in Association with Anesthesia, Operation and Postoperative Stress

INCIDENCE OF INTRA- AND POSTOPERATIVE ARRHYTHMIAS

The incidences of arrhythmias in association with specific types of surgery have been reported. Since none of these studies utilized continuous electrocardiographic monitoring, they represent minimal incidences of arrhythmias. In 82 patients 50 years of age or older who underwent lobectomy or pneumonectomy, there were 17 postoperative arrhythmias (defined as a rapid ectopic rhythm with a ventricular rate of 150 or more).[29] In a similar group of 68 patients aged 55 or more who had not received digitalis preoperatively, 52 developed postoperative arrhythmias.[30] Shields and Ujiki[31] reported seven arrhythmias in 50 nondigitalized patients undergoing pulmonary surgery.

Cardiac surgery is associated with an even higher incidence of arrhythmias than noncardiac operations. Of 146 consecutive patients undergoing repair of secundum atrial septal defects, 43 per cent developed postoperative arrhythmias.[32] In a series of 150 patients undergoing repair of a variety of congenital and acquired cardiac lesions, significant arrhythmias occurred in 30 per cent.[33]

TYPES OF POSTOPERATIVE ARRHYTHMIAS

In nearly every reported series, atrial fibrillation or flutter has been the arrhythmia noted most frequently in the postoperative period. In table 1 the incidences of all types of postoperative arrhythmias found in four series are shown. Atrial fibrillation or flutter accounts for 70 per cent of the 160 reported arrhythmias.

POTENTIAL MORBIDITY OF ARRHYTHMIAS

Morbidity and mortality secondary to arrhythmias are difficult to quantify. Arrhythmias are often associated with other serious complications; cause and effect are difficult to distinguish.

The sequelae of postoperative arrhythmias are determined in large part by the preoperative status of the patient. In young patients without heart disease, prolonged rapid tachycardia may be well tolerated. However, in elderly patients with marginal cardiac reserve, a fatal outcome may ensue. Acute heart failure, hypotension, hypoxia, myocardial ischemia, or progression to fatal arrhythmias may occur.

FACTORS PREDISPOSING TO ARRHYTHMIAS

Advanced Age. There is a clear increase in the incidence of postoperative arrhythmias with increasing age. This was well documented in a series of patients undergoing the same operation, closure of a secundum atrial septal defect. In 76 patients less than 18

years old, the incidence of arrhythmias was 32 per cent. In 17 patients more than 35 years old, the incidence was 83 per cent.[32] Each of the 14 postoperative arrhythmias reported by Shields and Ujiki[31] occurred in patients over the age of 62 years.

Pre-existent Heart Disease. Although none of the nine patients with postoperative arrhythmias reported by Lavine[3] had histories of overt heart failure, one had rheumatic heart disease, one had hypertensive cardiovascular disease, two had cardiac enlargement and two had histories of symptomatic recurrent tachycardia. Of ten patients with postoperative arrhythmias reported by Krosnick and Wasserman[29] seven had pre-existent heart disease. Of the 50 patients with postoperative arrhythmias reported by Rogers *et al.*,[34] 29 had heart disease.

Thus, the patients most vulnerable to the effects of arrhythmias, the elderly and patients with heart disease, also are predisposed to development of arrhythmias.

Type of Surgery. The incidence of arrhythmias is increased in association with thoracic and cardiac surgery.[29, 33] The exact incidence of arrhythmias in association with other specific major non-thoracic operations is not well documented.

Effect of Digitalis on Postoperative Arrhythmias

When either of the most common postoperative arrhythmias, atrial fibrillation and flutter, occurs in a patient who has been adequately digitalized, ventricular rate is significantly lower than in patients who have not been digitalized. The effect of preoperative digitalization on ventricular rate was studied in 53 patients who developed atrial fibrillation after mitral-valve surgery.[35] 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. Although there was considerable overlap, the average ventricular rate

during atrial fibrillation was significantly lower in patients who had been digitalized prior to operation.

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. Large doses of digitalis are necessary to slow ventricular rate in this setting.[35] In critically ill patients, rapid intravenous digitalization may result in toxicity unless close attention is given to the electrocardiogram and serum electrolytes. Many clinicians have not had extensive experience with such rapid-acting digitalis preparations as ouabain and, therefore, depend upon intravenous digoxin or lanatoside C for the treatment of rapid atrial fibrillation. With these drugs it is unlikely that rapid atrial fibrillation in previously undigitalized patients can be controlled in less than one or two hours, whereas when previously digitalized patients develop atrial fibrillation, ventricular rate can be slowed quickly by supplementary intravenous doses of digoxin or lanatoside C.

One objection to "prophylactic digitalization" has been the concept that when an arrhythmia occurs postoperatively it is easier to treat if the patient has not received digitalis because the possibility of digitalis toxicity need not be considered. However, postoperative arrhythmias fall into three categories, shown in table 1. The most common are those that indicate the need for additional digitalis even in patients previously digitalized: atrial fibrillation or flutter with rapid ventricular response. In this situation, digitalis toxicity would rarely be a consideration and therefore prior digitalization does not influence the choice of therapy but, rather, facilitates control of the arrythmia.

In the second group of potential postoperative arrhythmias, ventricular tachycardia or irritability and AV block, digitalis toxicity could be the cause. However, treatment of these arrhythmias is the same whether the patients have or have not received digitalis because digitalis is contraindicated. Thus, prior digitalization does not influence therapy if these arrhythmias occur.

TABLE 2. 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)

In the third group of potential postoperative arrhythmias, atrial tachycardia or nodal rhythm, digitalis toxicity is a potential cause and this possibility does influence therapy. However, the availability of the beta-adrenergic blocking agent, propranolol, reduces the therapeutic dilemma that these arrhythmias present when they occur in digitalized patients. Propranolol will be effective if these arrhythmias are due to digitalis toxicity or if they have occurred de novo.[36]

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.[30] In another series of patients undergoing pulmonary procedures, postoperative arrhythmias oc-

curred in seven of the 50 nondigitalized patients, but in only two of 73 digitalized patients.[31]

Recommendations for Digitalization Prior to Anesthesia and Operation (Table 2)

To Decrease the Incidence of Heart Failure

To decrease the incidence of heart failure secondary to the stress of anesthesia, operation and the postoperative period, it widely accepted that patients with signs and/or symptoms of heart failure should be adequately digitalized prior to operation.

We recommend that, in addition to patients with overt heart failure (in the absence of contraindications) patients with any of the following evidence of heart disease be digitalized before major operations:

1. History of heart failure, even though now well compensated.

2. Cardiac enlargement documented by chest x-ray.

3. Left or right ventricular hypertrophy disclosed by electrocardiogram.

4. Coronary artery disease as indicated by electrocardiogram, history of angina pectoris, or history of myocardial infarction.

To Modify the Incidence and Morbidity of Intra- and Postoperative Arrhythmias

As with overt heart failure, it is widely accepted that digitalis is indicated for patients with atrial fibrillation or flutter.

In addition to these patients, we recommend prophylactic digitalization of all patients who are especially predisposed to postoperative arrhythmias that are amenable to therapy with digitalis, and/or are especially vulnerable to the morbidity of arrhythmias:

1. Patients with histories of episodic atrial fibrillation or flutter.

2. All patients undergoing cardiac surgery unless they have subaortic stenosis or heart block.

3. Patients over the age of 50 years who are to undergo major pulmonary surgery.

4. Patients with aortic stenosis or mitral stenosis, with or without cardiac enlargement or ventricular hypertrophy disclosed by electrocardiogram.

Age and Digitalization

We do not believe that advanced age *per se* should be used as an indication for preoperative prophylactic digitalization. It is clear that the incidence of arrhythmias increases with age, and that the potential morbidity of arrhythmias is increased in the elderly. However, we believe that these increases in incidence and morbidity reflect the increased incidence of heart disease in the elderly. Careful preoperative evaluation, including chest x-ray and electrocardiogram, will detect heart disease in the elderly and allow selection of those patients who should be digitalized prior to major operations.

Methods of Digitalization

A variety of digitalis preparations have been isolated and synthesized since Withering's report of the beneficial effects of foxglove in the 18th century. Table 3 compares the digitalis preparations commonly used. The dosage of digitalis needed to manage congestive heart failure or arrhythmias is influenced by several factors. Increased sensitivity to digitalis is found in aged and debilitated patients [38] and in patients with myxedema or renal failure.[39] The well-known potentiation of digitalis toxicity by hypokalemia indicates that vigorous diuresis should not be performed while the patient is being digitalized. The serum potassium concentration should be assessed before and during digitalization, particularly in patients receiving diuretics. The narrow range between the therapeutic and the toxic dose of digitalis is well known, the therapeutic dose being approximately 60 per cent of the toxic dose.[5]

In the presence of atrial fibrillation or flutter, ventricular rate serves as an excellent guide to digitalis dosage. Preoperatively, digitalis dosage should be adjusted to allow a ventricular rate comparable to the rate that would be anticipated in the presence of normal sinus rhythm. The heart-rate response to mild exercise may be used as a guide to adequacy of digitalization. Similarly, in the intra- and postoperative periods, digitalis dosage should be guided by ventricular rate in the patient with atrial fibrillation or flutter. Cardioversion by electrical means is not recommended preoperatively because of the high probability of reversion to atrial fibrillation during or after operation. Prophylactic preoperative administra-

TABLE 3. Comparative Chart of Digitalis Preparations

	Digitalis Whole Leaf (Source: *Digitalis purpurea*)	Digitoxin (Source: *Digitalis purpurea*)	Lanatoside C (Source: *Digitalis lanata*)	Digoxin (Source: *Digitalis lanata*)	Ouabain (Source: *Strophanthus gratus*)
Average adult dose:					
For complete digitalization					
iv (or im)	—	1.0–1.5 mg	1.0–1.6 mg	1.0–2.0 mg	0.3–1.0 mg
Oral	1.5 g	1.0–1.5 mg	5.0–10.0 mg	2.0–3.0 mg	—
For maintenance (oral)	0.1 g	0.1–0.2 mg	0.5–1.5 mg	0.25–0.50 mg	—
Absorption from gastrointestinal tract	slow incomplete	slow almost complete	variable	rapid 80 percent absorbed	
Onset of action					
Oral					
Initial effect	3–4 hours	2–4 hours	variable	1 hour	—
Maximum effect	8–24 hours	6–12 hours	6 hours	6 hours	—
Intravenous					
Initial effect		0.5–2 hours	10–15 min	10–20 min	3–10 min
Maximum effect		8–9 hours	1–3 hours	1–3 hours	30–60 min
Elimination rate	14–21 days	14–21 days	2–5 days	2–5 days	1–3 days
Duration of toxicity from overdosage	3–14 days	3–14 days	1–2 days	1–2 days	1 day

TABLE 4. Methods for Digitalization of Patients Who Have Not Received Digitalis within Last 30 Days

Time Period to Digitalize	Preparation	Route	Average Total Digitalizing Dose (mg)	Initial Dose (mg)	Schedule
72 hours	Digoxin	po	2.5	0.25	0.25 mg po/q6h for 8–12 doses
	Digitoxin	po	1.2	0.1	0.1 mg q6h for 12 doses
24 hours	Digoxin	po	2.5	1.0	1.0 mg po, then 0.5 mg po q 8h for 2–4 doses
	Digitoxin	po	1.2	0.6	0.2 mg po q6h for 3–4 doses
8 hours	Digoxin	iv	1.25	0.5	0.5 mg iv, then 0.25 mg iv q2h for 2–4 doses
4 hours	Digoxin	iv	1.25	1.0	1.0 mg iv, then 0.25 mg iv q2h for 1–2 doses
	Lanatoside C	iv	1.4	1.0	1.0 mg iv, then 0.2 mg iv q2h for 1–3 doses
1 hour	Ouabain	iv	0.5	0.25	0.25 mg iv (slowly), then 0.1 mg q20–30 minutes for 1–3 doses

tion of quinidine or procainamide is to be discouraged because they cause myocardial depression.[40, 41]

In patients in normal sinus rhythm, the digitalizing dose is largely empirical and essentially involves administration of a total dose that has been found to result in adequate digitalization without toxicity in the *average* patient. Thus, the "digitalizing doses" shown in table 3 are useful only as guides. If evidence of toxicity occurs before the total recommended dose is given, further digitalis should be withheld. In general, it is better to err on the side of under-digitalization preoperatively, especially in patients about to undergo cardiopulmonary bypass. It is safer to add digitalis intra- or postoperatively than to deal with digitalis toxicity. In table 4, methods of effecting digitalization in various time periods are presented. The safest method of digitalization is by the oral route, over a period of 48 to 72 hours. Rapid intravenous digitalization should be reserved for urgent circumstances when it is necessary to digitalize in less than eight hours. In patients who are to undergo elective surgery, proper planning will allow adequate time for oral digitalization and several days on maintenance dosage before operation. In patients who cannot take oral medication, digitalization may be intramuscular or intravenous. The intravenous route is preferred in patients with peripheral edema or impaired peripheral perfusion because of uncertainties of absorption.

The digitalis preparation chosen obviously reflects individual experience. Digitoxin and digoxin are the two oral preparations most frequently used. Many believe that digoxin is ideal for the surgical patient because it can be given orally, intramuscularly, or intravenously and because it is rapidly eliminated, thus resulting in less prolonged toxicity than digitalis leaf or digitoxin.[42]

Digitalis Toxicity

Gastrointestinal manifestations, including anorexia, nausea, vomiting and, occasionally, diarrhea are usually the earliest signs of digitalis toxicity.[43]

Cardiac toxicity, as evidenced by arrhythmias, is the most dangerous result of digitalis excess. Of the great variety of arrhythmias that may result from digitalis overdosage, four constitute 70 per cent to 80 per cent of the arrhythmias due to digitalis toxicity: 1) premature ventricular contractions; 2) heart block; 3) A-V dissociation; 4) nodal rhythm.[43] Although paroxysmal atrial tachycardia with A-V block is relatively specific for digitalis toxicity, it is seen less frequently than the above arrhythmias.[43] Steps in the management of digitalis toxicity include:

1. Withdrawal of digitalis.

2. Potassium chloride administration. In the absence of renal impairment, potassium chloride may be administered orally (4–8

g/day) or intravenously (40 mEq in 500 ml 5 per cent dextrose in water).

3. Other treatment. For urgent treatment of ventricular irritability, intravenous lidocaine (1 mg/kg) is usually effective.[44] If ventricular irritability recurs, the same dose may be repeated or a slow infusion (1 mg/ml in 5 per cent dextrose in water) may be used. Alternative therapy for ventricular irritability includes quinidine, procainamide, or diphenylhydantoin (Dilantin).

Serious supraventricular arrhythmias resulting from digitalis excess, including atrial tachycardia, may be treated with propranolol, a beta-adrenergic blocking agent. One to 5 mg given intravenously at a rate of 0.5 to 1.0 mg/min usually abolishes the arrhythmias.[36] Caution must be exercised in the administration of propranolol. Overt heart failure, bronchospasm and A-V block are contraindications to its use. Incipient heart failure is a relative contraindication. Administration of propranolol during general anesthesia may potentiate the myocardial depressant effects of the anesthetic.[45]

When arrhythmias occur with anesthesia and operation, causes other than digitalis should be sought before a diagnosis of digitalis intoxication is made. Hypoxia, hypercapnia, hypovolemia, fever, hypokalemia, or deep levels of anesthesia may results in arrhythmias that may be confused with digitalis intoxication. Treatment of these underlying complications frequently corrects the arrhythmia.

Summary

A review of the clinical pharmacology of digitalis and the effects of anesthesia, operation, and the postoperative period on myocardial function and cardiac rhythm leads us to conclude that in certain patients prophylactic digitalization is indicated prior to major operations.

It has been clearly established that digitalis has a positive inotropic effect in the presence or absence of heart failure. Thus, to prevent the development of heart failure in response to the multiple stresses of operation, we believe that prophylactic digitalization is indicated in all patients with clinical, electrocardiographic or radiographic evidence of organic heart disease, even in the absence of overt heart failure.

The most common postoperative cardiac arrhythmias are atrial flutter and atrial fibrillation, two arrhythmias for which digitalis is the treatment of choice. We recommend that patients predisposed to arrhythmias and patients particularly vulnerable to the effects of arrhythmias should be digitalized prior to operation.

Careful preoperative evaluation and appropriate digitalization of these patients will, we believe, decrease the incidence of postoperative heart failure and/or arrhythmias.

References

1. Moyer, J. H., Alexander, S. F., Brest, A. N., Dack, S., Kay, C. F., Keats, A. S., Mattingly, T. W., Metcalfe, J., Morris, G. C., Schreiner, G. E., Siekert, R. G., and Zinsser, H. F., Jr.: Panel Discussion I, Amer. J. Cardiol. 12: 363, 1963.
2. Selzer, A., Kelly, J., Jr., Gerbode, F., Kerth, W. J., Osborn, J. J., and Popper, R. W.: Case against routine use of digitalis in patients undergoing cardiac surgery, J.A.M.A. 195: 549, 1966.
3. Levine, S.: Acute cardiac upsets, occurring during or following surgical operation, J.A.M.A. 75: 795, 1920.
4. Erlanger, H.: Cardiac arrhythmias in relationship to anesthesia: Past and present concepts, Amer. J. Med. Sci. 243: 651, 1962.
5. Lown, B., Black, H., and Moore, F. D.: Digitalis, electrolytes and the surgical patient, Amer. J. Cardiol. 6: 309, 1960.
6. Talmage, E. A.: The role of ouabain in myocardial insufficiency during anesthesia and surgery, Amer. J. Cardiol. 6: 747, 1960.
7. Braunwald, E., Mason, D., and Ross, J., Jr.: Studies on the cardiocirculatory actions of digitalis, Medicine 44: 233, 1965.
8. Bloomfield, R. A., Rapoport, B., Milnor, J. P., Long, W. K., Mebane, J. G., and Ellis, L. B.: The effects of the cardiac glycosides upon the dynamics of the circulation in congestive heart failure, J. Clin. Invest. 27: 588, 1948.
9. Braunwald, E.; (Discussants) Chidsey, C. A., Pool, P. E., Sonnenblick, E. H., Ross, J., Jr., Mason, D. T., Spann, J. F., and Covell, J. W.: Congestive heart failure: Biochemical and physiological considerations, Ann. Int. Med. 64: 904, 1966.
10. Koch-Weser, J.: Mechanism of digitalis action on the heart, New Eng. J. Med. 277: 417, 1967.
11. Price, H. L., and Helrich, M.: The effect of cyclopropane, diethyl ether, nitrous oxide, thiopental and hydrogen ion concentration on the myocardial function of the dog heart–

lung preparation, J. Pharmacol. Exp. Ther. **115:** 206, 1955.

12. Flacke, W., and Alper, M. H.: Actions of halothane and norepinephrine in the isolated mammalian heart, ANESTHESIOLOGY **23:** 793, 1962.

13. Jones, R. E., Linde, H. W., Deutsch, S., Dripps, R. D., and Price, H. L.: Hemodynamic actions of diethyl ether in normal man, ANESTHESIOLOGY **23:** 299, 1962.

14. Jones, R. E., Guldman, N., Linde, H. W., Dripps, R. D., and Price, H. L.: Cyclopropane anesthesia III. Effects of cyclopropane on respiration and circulation in normal man, ANESTHESIOLOGY **21:** 380, 1960.

15. Deutsch, S., Linde, H. W., Dripps, R. D., and Price, H. L.: Circulatory and respiratory actions of halothane in normal man, ANESTHESIOLOGY **23:** 631, 1962.

16. Clowes, G. H., Del Guercio, L. R., and Barwinsky, J.: Circulatory response to the trauma of surgery and its relationship to chemical homeostasis, Circulation **22:** 734, 1960.

17. Boyd, A. D., Tremblay, R., Spencer, F. C., and Bahnson, H. T.: Estimation of cardiac output soon after intracardiac surgery with cardiopulmonary bypass, Ann. Surg. **150:** 613, 1959.

18. Clowes, G. H., Jr., and Del Guercio, L. R.: Circulatory response to trauma of surgical operations, Metabolism **9:** 67, 1960.

19. Goldberg, A. H., Maling, H. M., and Gaffney, T. E.: The effect of digoxin pretreatment on heart contractile force during thiopental infusion in dogs, ANESTHESIOLOGY **22:** 975, 1961.

20. Goldberg, A. H., Maling, H. M., and Gaffney, T. E.: The value of prophylactic digitalization in halothane anesthesia, ANESTHESIOLOGY **23:** 207, 1962.

21. Shimosato, S., and Etsten, B.: Performance of digitalized heart during halothane anesthesia, ANESTHESIOLOGY **24:** 41, 1963.

22. Braunwald, E., Bloodwell, R. D., Goldberg, L. I., and Morrow, A.: Studies on digitalis. IV. Observations in man on the effects of digitalis preparations on the contractility of the nonfailing heart and on total vascular resistance, J. Clin. Invest. **40:** 52, 1961.

23. Mason, D. T., and Braunwald, E.: Studies on digitalis. IX. Effects of ouabain on the nonfailing human heart, J. Clin. Invest. **42:** 1105, 1963.

24. Cooper, T., Willman, V., Zafiracopoulos, P., and Hanlon, C. R.: Effect of prophylactic digitalization on myocardial function after elective cardiac arrest, Ann. Surg. **151:** 17, 1960.

25. Lombardo, T. A., Radigan, L. R., and Morrow, A. G.: Myocardial failure in experimental hypothermia, Circ. Res. **5:** 22, 1957.

26. Crowell, J. W.: Digitalization as a treatment for irreversible hemorrhagic shock, Circulation **24:** 912, 1961.

27. Braunwald, E., and Williams, J., Jr.: Effect of prophylactic digitalization on the development of heart failure and myocardial hypertrophy, Circulation, Suppl. 3, **30:** 53, 1964.

28. Kahler, R. L., Thompson, R. H., Buskirk, E. R., Frye, R. L., and Braunwald, E.: Studies on digitalis. VI. Reduction of the oxygen debt after exercise with digoxin in cardiac patients without heart failure, Circulation **27:** 397, 1963.

29. Krosnick, A., and Wasserman, F.: Cardiac arrhythmias in the older age group following thoracic surgery, Amer. J. Med. Sci. **230:** 541, 1955.

30. Wheat, M. W., and Burford, T. H.: Digitalis in surgery: Extension of classical indications, J. Thorac. Cardiov. Surg. **41:** 162, 1961.

31. Shields, T., and Ujiki, G. T.: Digitalization for prevention of arrhythmias following pulmonary surgery, Surg. Gynec. Obstet. **126:** 743, 1968.

32. Popper, R., Knott, J. M., Selzer, A., and Gerbode, F.: Arrhythmias after cardiac surgery, Amer. Heart J. **64:** 455, 1962.

33. Williams, J., Jr., Morrow, A., and Braunwald, E.: The incidence and management of "medical" complications following cardiac operation, Circulation **32:** 608, 1965.

34. Rogers, W., Wroblewski, F., and LaDue, J.: Supraventricular tachycardia complicating surgical procedures, Circulation **7:** 192, 1953.

35. Selzer, A., and Walter, R. M.: Adequacy of preoperative digitalis therapy in controlling ventricular rate in postoperative atrial fibrillation, Circulation **34:** 119, 1966.

36. Epstein, S. E., and Braunwald, E.: Beta-adrenergic receptor blocking drugs. Mechanisms of action and clinical applications, New Eng. J. Med. **275:** 1106, 1966.

37. Kay, C. F.: The clinical use of digitalis preparations, Circulation **12:** 1, 1955.

38. Dall, J. L.: Digitalis intoxication in elderly patients, Lancet **1:** 194, 1965.

39. Braunwald, E., and Klocke, F. J.: Digitalis, Ann. Rev. Med. **16:** 371, 1965.

40. Harrison, D. C., Sprouse, J. H., and Morrow, A. G.: The antiarrhythmic properties of lidocaine and procaine amide, Circulation **28:** 486, 1963.

41. Mierzwiak, D. S., Mitchell, J. H., and Shapiro, W.: The effect of diphenylhydantoin (Dilantin) and quinidine on left ventricular function in dogs, Amer. Heart J. **74:** 780, 1967.

42. Friend, D. G.: Cardiac glycosides, New Eng. J. Med. **266:** 300, 1962.

43. Dubnow, M. H., and Burchell, H. B.: A comparison of digitalis intoxication in two separate periods, Ann. Int. Med. **62:** 958, 1965.

44. Likoff, W.: Cardiac arrhythmias complicating surgery, Amer. J. Cardiol. **3:** 427, 1959.

45. Craythorne, N., and Huffington, P.: Effects of propranolol on the cardiovascular response to cyclopropane and halothane, ANESTHESIOLOGY **27:** 580, 1966.