Wisely used balanced anesthesia provides the severely ill patient with a relatively safe and physiologic stable experience. The proper combinations of hypnotics, relaxants, and analgesics at each particular moment are essential for such success. The author clearly explains what anesthetic drugs are used for open-heart surgery at Duke University Medical Center and what precise effects these drugs have on the patient.

Narcotic anesthesia has been in use for many years, but the recent interest in moderate-to-large-dose morphine general anesthesia for heart surgery has caused us to re-examine and re-think the role of analgesics in anesthetic practice today. In any patient who is anesthetized for a surgical procedure, there are three basic anesthetic requirements: (1) hypnosis, (2) muscular relaxation, and (3) analgesia.

**Hypnosis**

Hypnosis, for want of a better word, is what may be defined as the patient's diminution of fear, anxiety, and memory of what happened to him during a surgical procedure. There are many ways in which this can be achieved. Classically, the major anesthetics, such as alcohol, nitrous oxide, ether, and chloroform, in that order historically, were used to provide hypnosis. The assumption was made that once unconscious, the patient no longer had any fear, anxiety, nor memory of what had occurred.

Later, a large group of drugs known as barbiturates became available, and it quickly became apparent that these drugs were superb agents for providing what we have defined as hypnosis. Perhaps the most common of these used today are pentobarbital (Nembutal®) for premedication, and thiopental (Pentothal®) for rapid induction of anesthesia.

More recently, another large group of drugs, loosely called tranquilizers, have become available which have diverse effects on the higher centers of the brain. These are widely varied and strange agents which will only be mentioned in passing. Three examples are promethazine, chlorpromazine, and droperidol. A newer anesthetic, ketamine, produces profound hypnosis and moderate to good analgesia but no muscular relaxation. It is used primarily in infants and children too apprehensive to allow a graceful initiation of an intravenous. It can be administered intramuscularly.

Most important of all, hypnosis can be produced by the pre-anesthetic visit. Time and effort with the patient before surgery can do much to relieve fear and anxiety, and cause a tranquil and relaxed patient to arrive prior to the induction of anesthesia.

**Muscular relaxation**

The second major anesthetic requirement is, of course, the muscular relaxation that is necessary to perform the technical maneuvers of both the anesthesiologist and the surgeon. Again, classically the major anesthetics such as ether and chloroform provided this relaxation by their direct curare-like action.

More recently, specific myoneural junction inhibitors were discovered and used clinically, heralded by the discovery of curare by Griffith in 1942. These fall roughly into two groups, the competitive blockers such as curare or pancuronium, and the depolarizing agents such as succinylcholine.
A third common way to provide muscular relaxation is by the use of regional anesthesia such as spinal, axillary block, and others.

Analgesia

Analgesia, which is the principal concern here, has long been provided for patients by a variety of techniques and agents including alcohol, morphine, and hypothermia. Regional and topical anesthesia also reaches into antiquity. It is quite probable that the Inca Indians used cocaine; and it was introduced into modern medicine in 1885 by Corning in New York, who performed a spinal anesthetic with it. This was quickly followed by procaine in the early 20th century. All of the major anesthetics mentioned above provide varying degrees of analgesia, with diethyl ether probably being the best and halothane the least analgesic agent. Deep hypnosis in the classical sense and acupuncture are also ancient remedies for pain which have experienced a recent revival.

Most commonly, however, specific pharmacological agents are employed to provide analgesia in our patients. These drugs could be divided into mild analgesics such as aspirin, acetaminophen, and pentazocine, and the moderate to strong analgesics such as meperidine, morphine, and fentanyl. Although these drugs have many diverse actions, they are best noted for their analgesic property.

Only three of the common analgesics will be mentioned here: morphine, meperidine (Demerol®), and fentanyl (Sublimaze®). Morphine, a derivative of opium, has its pharmacology and chemistry well outlined in Goodman and Gilman, and we will only mention some of its major actions in passing. The primary effect of morphine, as in all commonly used narcotics, is analgesia. The analgesic effect can become profound before the other effects are severe and can persist after many of the side effects have nearly disappeared.

Morphine also produces some hypnosis; its euphoric action is well known. Respiration is severely depressed, particularly the rate, but also the tidal volume. An overdose of this drug, like most narcotics, results in death through respiratory depression. Since postoperative open-heart patients are mechanically ventilated by plan, this side effect (which is usually deleterious) has now become advantageous. The patient rests comfortably, has little or no pain, and does not "fight" the respirator.

In addition, morphine causes profound constriction of the pupils and stimulation of visceral smooth muscle. One of the possible severe results of this action can be pancreatitis, caused by spasm of the sphincter of Oddi and hence obstruction of the pancreatic ducts. Last year, indeed, there were four cases of pancreatitis in open heart patients at the Duke University Medical Center who had had morphine, but in the over 400 patients done since then, there has not been a single instance. It is difficult, therefore, to discern whether this is a more theoretical or real hazard.

All of the narcotics reduce oxygen consumption, which is a particularly useful effect in patients with coronary artery disease and others who have borderline oxygenation. All narcotics are, of course, addictive, but there is no evidence, to my knowledge, that used in the acute situation for surgical procedures they have caused any patient to become addicted. Proper withdrawal from the drug, of course, is necessary as soon as analgesia is no longer needed. These drugs also decrease peripheral vascular resistance, both arterial and venous, and therefore, large doses can cause a severe drop in blood pressure in susceptible patients.

Meperidine (Demerol®) differs little from morphine except that perhaps its analgesia is less and the incidence of nausea, vomiting, and hypotension (probably due to histamine release) is perhaps greater. At the Duke University Medical Center, it is used primarily for premedication rather than as the major anesthetic at the present time.

Fentanyl (Sublimaze®) has the advantage of perhaps causing less smooth muscle spasm than either morphine or meperidine, perhaps less nausea and vomiting, and possibly less hypotension, although this as yet has not been well documented. In patients with bronchial asthma, the drugs of choice probably would be fentanyl, then morphine, then meperidine, in that order.

Fentanyl has one distinct advantage over the other two drugs; it is very short acting. If quick analgesia is needed without prolonged side effects, fentanyl is an ideal drug.
Romagnoli has done a careful study measuring the relative analgesic potency and duration of action of fentanyl and morphine. His results show that fentanyl is 77 times as potent as morphine and that the duration of morphine is approximately three times longer than that of fentanyl.9

The trend in anesthesia today is to use a balanced anesthetic technique. This implies the utilization of a number of drugs to provide the anesthetic requirements outlined above, each with their own particular action or actions. Whereas 20 years ago diethyl ether alone might have been used to provide hypnosis, muscular relaxation, and analgesia, today a combination of drugs more likely would be employed. For example, thiopental might be given for hypnosis, succinylcholine for muscular relaxation, and nitrous oxide and meperidine drip for analgesia.

When discussing the philosophy of balanced anesthesia, there appears an ancient and little known law (invented at this writing) which states that “all medicine is a gamble”. There are two corollaries to this law: (1) all surgery is destructive; and (2) all anesthetics are poisons. It would follow, therefore, that the less of an anesthetic agent we administer to our patient, the less harm we should do. The rationale for this is that most of our anesthetic agents are detoxified in the liver or eliminated by the kidney.

Recent evidence is accumulating that even our so-called undetoxified agents, such as halothane and methoxyflurane, do indeed undergo considerable degradation by liver enzymes. By utilizing a large number of anesthetic agents and giving the patient only small quantities of each, any given organ or enzyme system would not be overloaded, and hence, could theoretically detoxify and remove the anesthetic agents more quickly than if a massive dose of one single agent were administered. Since it is possible to administer a balanced anesthetic skillfully and have the patient wide awake and alert at the end of surgery with a minimal amount of postoperative pain, it would seem that the clinical experience correlates at least somewhat with this theory.

Twenty years ago at Duke Hospital, under the guidance of Dr. C. Ronald Stephen, many patients were given a balanced anesthetic using thiopental, nitrous oxide, and meperidine drip. Those of us involved in this study quickly learned that great skill and judgement were necessary to do this; but if this technique was properly employed, the rewards were great. It was discovered that the dose of thiopental could be reduced one-half or less in a three-or four-hour case by the judicious addition of the meperidine drip. The patient would be as awake, indeed perhaps even more alert, at the end of surgery as with thiopental and nitrous oxide alone.

The trick is to use as little as possible of each agent to achieve the desired end. Conversely, one must be careful not to fall into the trap of not having the patient adequately anesthetized. This has led in some cases to severe bronchospasm, tachycardia and other dangerous arrhythmias, and poor operating conditions for the surgeon. Light but adequate anesthesia is a philosophy not to be talked about, but rather to be meticulously practiced.

Each agent must be used for its own best purpose. For example, if the patient becomes too lightly anesthetized, additional thiopental might be used. If, however, surgical stimulation causes the patient to react, obviously more analgesic must be administered. The whole crux of the difference between “polypharmacy” and “balanced anesthesia” lies in strict adherence to these principles. Good “balanced anesthesia” requires a good mentally balanced anesthetist.

Special requirements for the cardiac patient

With the recent resurgence of interest in balanced anesthesia and the use of morphine in particular for open-heart surgery, there are some special requirements for the cardiac patient that need to be mentioned. It should be obvious that one of the major requirements is that any agent employed must produce a very minimal amount of myocardial depression in these patients with already sick hearts. Bailey in 1958 first recommended the use of narcotics as general anesthetics for cardiac surgery. Lowenstein in 1969 demonstrated that morphine, even in large doses, produced a minimal myocardial depression.8

Halothane and methoxyflurane, however, when used in doses below MAC also produce a minimal myocardial depression.
These agents have become more popular in recent years for cardiac surgery. Methoxyflu-
rane, of course, is a longer acting drug and becomes extremely soluble in the fatty tis-
sues, particularly with hypothermia, so the dosage must be very carefully monitored. The renal damage reported with the use of methoxyflurane is probably minimal at MAC or below. A newer analgesic, fentanyl, is also very useful, particularly for short cases, as it will wear off in about one-third the time that morphine will.

Important only secondarily to myocar-
dial depression is the effect of the anesthetic agents on vascular resistance. This is par-
ticularly critical in patients who have severe aortic insufficiency where a loss of vascular tone could lower the arterial mean blood pressure, and hence, not provide adequate coronary blood flow. The result is myocardial ischemia and decreased cardiac output with disastrous results.

In children with large left-to-right shunts who are not cyanotic, a sudden drop in vascular resistance may reverse their shunt to right-to-left with a sudden and catastrophic decrease in arterial oxygen saturation. Probably the least harmful drug in this regard is methoxyflurane. Taylor uses methoxyflurane in concentrations of 0.2 to 0.3 per cent along with thiopental, nitrous oxide, and muscle relaxants.

Strangely enough, halothane, which we all think of as being a potent vasodilator, in doses below MAC really has a minimal effect. It causes some transient decrease in arterial peripheral resistance but seems to have very little effect on the tone of the venous vascular bed at these concentrations. Thiopental also can cause a decrease in vascular resistance, and hence, must be administered slowly and carefully or the vasodilation may be more profound than with a halothane induction.

On the other hand, morphine, which looks like the most promising agent from the standpoint of minimal myocardial depres-
sion, has a profound effect on vascular tone. Stanley has demonstrated a significantly greater requirement for blood transfusion with morphine anesthesia than with halo-
thane. He also has noted a significant de-
crease in renal function with morphine. He postulates that the morphine has a profound effect on the venous tone as well as the ar-
terial tone and that this causes significant pooling of blood in the venous vascular space with a concomitant decrease in effective blood volume. Renal blood flow, therefore, decreases and oliguria results. As a result, more diuretics are needed in the morphinized patients, according to Stanley.

As mentioned previously, a decrease in oxygen consumption can be very beneficial to patients with poor circulation. Recently, some good work has been done on the specific oxygen consumption of certain drugs under carefully controlled conditions. Sari has shown that Innovar®, for example, has no effect on cerebral blood flow or mean cerebral oxygen consumption in ten human subjects. The cerebral blood flow increased from 48–51 ml/100 gm/minute, the pCO₂ from 34–37 mm/Hg, and the mean cerebral oxygen consumption from 3.06–3.08 ml/100 gm/minute. None of these changes were significant.

It would appear, therefore, that Innovar® would not be a good drug to use in open heart surgery for coronary artery disease. On the other hand, Wong has demonstrated a significant reduction in total body oxygen consumption using morphine with oxygen and nitrous oxide in man. Five minutes after the administration of 2 mg/kg body weight of morphine sulfate intravenously, the oxygen consumption decreased from 279 to 177 ml/minute, a 37 per cent drop. After 15 minutes it was 26 per cent, in 30 minutes 23 per cent, in 60 minutes 31 per cent. This study was done on ten normal human sub-
jects, indicating an overall average decrease of about one-third in oxygen consumption. The benefits of this are ob-
vious.

Another requirement for anesthetic drugs used in heart surgery is that they have a minimal effect on the cardiac rhythm. Prob-
ably, in small doses, none of the drugs com-
monly used has any serious effect on rhythm. Acid base balance, electrolyte balance, digitalization, and other biochemical-physiologi-
cal factors are far more important in pro-
ducing a stable rhythm than any particular agent used. If, however, a serious ventricular rhythm persists, for example under halo-
thane anesthesia, discretion dictates consid-
eration of discontinuing the agent and using another. It is extremely important that the
blood level of all anesthetics be minimal during actual manipulation of the heart itself. During this critical time, muscular paralysis and average doses of nitrous oxide usually will maintain unconsciousness with a minimal effect on the heart.

It is obvious that good analgesia is necessary during surgery, not only for humane reasons, but for very good physiologic ones also. Too light anesthesia may cause a severe epinephrine release which will increase oxygen consumption, increase the likelihood of ventricular arrhythmias, and stress the myocardium. The rise in blood pressure during nasotracheal intubation, skin incision, and so on, indicates that more analgesia should be provided. If this is ignored and the blood pressure is allowed to rise too far, the severe hypertension will stress the myocardium by creating a greater afterload for the left ventricle to pump against. This can be as dangerous to the coronary patient as a severe hypotension.

From the surgical standpoint, hypertension will also cause increased bleeding. This is particularly important with a heparinized patient. During partial cross-clamping of the aorta for coronary grafts, it is also extremely important that blood pressure be kept at the most acceptable minimum. Hypertension at this point could tear the aorta and be fatal for the patient.

The pharmacological effects of certain drugs which previously were considered undesirable side effects, can now be utilized to maintain a proper blood pressure in your patient. Morphine, for example, provides good analgesia and some vasodilation. Henney has shown that morphine anesthesia initially causes vasodilation lasting about 30 minutes. Vasconstriction then sets in and the blood pressure gradually rises to a level higher than the original pressure.8

For this reason, with morphine anesthesia one must watch carefully for hypertension later in the case. This is confirmed by Conahan et al., who demonstrated under carefully controlled conditions that more hypertension occurred with morphine than with other agents.8 In addition to halothane, such adjunct agents as chlorpromazine, large doses of steroids, trimethaphan (Arfonad®) or nitroprusside can be employed to control this hypertension.

Open-heart surgery at Duke University Medical Center

It might be of interest now to describe in detail how we manage a patient for open-heart surgery at Duke University Medical Center with regard to the anesthetic agents. Premedication is administered at 6:00 a.m. by the intramuscular route and usually consists of morphine or diazepam (Valium®) or a combination of both. The choice of drugs and amount is a matter of individual judgement. If the patient is very anxious and fearful, diazepam is usually administered.

Anticholinergic drugs are usually not given, as tachycardia is to be avoided. In some of the children, however, we have been trying a meperidine and scopolamine combination to provide amnesia. Children, of course, can tolerate tachycardia better than adults. Scopolamine probably causes slightly less tachycardia than does atropine. If ketamine anesthesia is anticipated, an anticholinergic agent is always given to reduce secretions. Pediatric anesthesia for open-heart surgery will not be discussed further here as this is an extensive subject in itself.

The patient is brought to the induction room at 6:30 a.m., at which time his premedicant drug should be reaching its peak. A blood pressure cuff is applied to the patient and an intravenous started with a large bore (16 or 14 gauge) Teflon catheter. Means to apply positive pressure oxygen breathing and to administer necessary resuscitant drugs are readily at hand.

With the patient, therefore, under careful control, more pre-anesthetic medication is given as needed. This may consist of divided doses of morphine of approximately 5 mg each, or Innovar® of 0.5 cc each. This is to make the patient more tranquil and less fearful, which is extremely important in these cardiac patients. If they become unduly frightened and release epinephrine, they can develop hypertension and severe coronary constriction. Also, the morphine, as well as the fentanyl in the Innovar®, provide further analgesia for the multiple needle sticks that the patient is about to receive. These include a second intravenous, a central venous pressure catheter, an arterial catheter (usually in the radial), and possibly electroencephalographic leads.

The patient is then moved from the in-
duction room into the operating room where all of the monitors are attached, calibrated, and checked. During this time the patient is administered 100 per cent oxygen by mask. Samples for arterial blood gases and acid-base determinations are taken with the patient breathing room air and again after 10 minutes of inhalation of 100 per cent oxygen. This gives us two points on the dissociation curve of oxyhemoglobin and tells us a little more about the patient's preoperative pulmonary function.

When all is in readiness, thiopental for hypnosis in about 50 mg increments, 50 per cent nitrous oxide for analgesia, and oxygen are administered to the patient. If he is severely ill or has a large right-to-left shunt, a higher concentration of oxygen is used. Further analgesia is provided by intermittent doses of morphine, usually in 5 mg increments. In spite of the use of topical anesthesia, passing a nasotracheal tube through the nose may be painful and tracheal reflexes may be elicited. For this reason it is necessary to have some morphine "on board" before this procedure is done.

As soon as the patient is unconscious and it is established that he has a good airway and tight mask fit so that intermittent positive pressure ventilation can be applied, the muscle relaxant, usually pancuronium bromide, is administered. A second-hand clock is started and closely observed. Pancuronium peaks in 3–5 minutes, so that intubation may be attempted any time after that. Some anesthesiologists (Dr. Davis at Duke University Medical Center) have suggested that pancuronium bromide and other relaxants might in fact have some anesthetic effect in addition to their muscle paralyzing effect.

Clinically it does seem that induction goes smoothly with pancuronium. In Duke University Medical Center bypass patients, however, a large enough dose of pancuronium is administered to carry the patient through the entire procedure, at least up to the bypass time. The usual recommended dose is about 0.1 mg/kg; but we use nearer to 0.15 mg/kg since we want no motion pre-bypass, and we plan to support the patient's ventilation afterwards. 8, 14 This provides profound relaxation, so that nasotracheal intubation is facilitated, and we do not have to worry about the patient moving during the first part of the case when we are extremely busy with other maneuvers.

Topical anesthesia is provided by 10 per cent cocaine in the nose (as this gives good vasoconstriction of the nasal mucosa) and 4 per cent xylocaine (usually by "Jack" spray) in the trachea. Cocaine causes some release of epinephrine which is useful to reverse the hypotension that may be developing from the morphine and thiopental. Although this may not sound too scientific, one can actually titrate the blood pressure to a certain degree by giving thiopental to lower it and cocaine to raise it. This sort of "fine tuning" is very useful in maintaining a stable cardiovascular system.

Maintenance of anesthesia is then achieved with morphine and nitrous oxide for analgesia, thiopental for hypnosis, and pancuronium bromide for muscular relaxation. The morphine is administered prior to painful stimuli such as skin clips, skin incision, and sternal splitting. The latter is extremely painful, and we usually have at least 1 mg/kg body weight of morphine on board before this procedure is begun. We use nitrous oxide in most cases to add hypnosis and some analgesia to our patient.

Anesthesiologists vary in their use of nitrous oxide. Stanley uses 10–30 per cent in most cases, 4 and Conahan uses 30–50 per cent. 5 They point out that even with 1–3 mg/kg body weight of morphine anesthesia, the patient is frequently not unconscious unless nitrous oxide is added. One of the major advantages of nitrous oxide is that it is a relatively good, although weak, analgesic. Some authors have suggested that nitrous oxide combined with morphine causes more venous dilatation, and therefore, they only use morphine and oxygen. Also, in the very ill patient, along with other agents, even moderate doses of nitrous oxide may cause some myocardial depression. This, however, as with all anesthetic agents, is probably a dose-related effect.

The proper dosage of all the anesthetic agents used in "balanced anesthesia" should suit the individual patient at the particular moment. At Duke, we use 50 per cent nitrous oxide in most cases; but if any difficulty is encountered with either oxygenation or the cardiovascular system, it is discontinued and
100 per cent oxygen is administered. The nitrous oxide normally is not discontinued until after the last skin stitch is placed in order to provide analgesia for the closure. It can be washed out in 3–5 minutes.

Thiopental is administered whenever the patient appears “light” as evidenced by the electroencephalogram or movement of the hand or head. A moderate dose (usually between 50 and 100 mg) is given just before going on cardiopulmonary bypass. The reason for this is that, at present, halothane or other volatile anesthetics are not being given via the pump, and pump washout is very rapid.

Ogawa has demonstrated that the maximal concentration of barbiturate in the oxygenator is achieved in about five minutes. After this time, the venous inflow to the oxygenator has very low concentrations of thiamylal (the particular drug he studied), and the arterial inflow from the oxygenator to the patient has very high concentrations. The washout rate, of course, was related to the perfusion flow rate. For example, at a perfusion of 100 ml/kg/min the washout of thiamylal from the patient into the oxygenator was twice as fast as when a flow rate of 60 ml/kg/min was employed.

For this reason, the patient is likely to wake up when bypass is started if he is not pre-primed with a little barbiturate. It is not harmful to be awake at this time, but the patient frequently remembers this and makes unfavorable comments to us about it afterwards. Also, during cardiopulmonary bypass, if the patient appears too “light” by the electroencephalogram or if a great deal of muscle relaxant is needed to abolish respiratory efforts, small additional doses of thiopental may be added directly to the pump-oxygenator. No hypnotic drugs such as barbiturates (thiopental) are administered to the patient in the post-bypass period. We like to have the patient wide awake with a “clear” brain at the end of the case.

Morphine is administered, usually in about 10 mg doses, into the heart lung pump just before coming off bypass to provide postoperative analgesia. Small doses of morphine also are administered toward the end of the case and in the acute care unit, as needed, to provide further postoperative analgesia. We attempt to have the patient wide awake and responsive to command, yet in a reasonably good analgesic state on arrival in the acute care unit. For this reason, we shy away from tranquilizers that might make the cerebral function “fuzzy” so that we can properly assess any cerebral damage from pumping, blood fragmentation, air embolism, and so on. During the first 24–48 hours, small doses of morphine (usually 1 or 2 mg) are given intravenously as needed for postoperative analgesia.

Although we plan to ventilate the patient postoperatively, we do wish enough of the pancuronium to be metabolized so that the patient can move all four extremities on command. This assures us that no paralysis has resulted from air embolism or hypoperfusion of spinal arteries. Also, we like the patient to be able to nod or shake his head so that he can answer questions intelligently. No attempt is made to reverse the pancuronium as long as the patient can move slightly. Also, the reversing medications (usually neostigmine and atropine mixtures) are highly dangerous to give to the cardiac patient. Although these mixtures are supposed to be in the proper ratio to prevent either tachycardia or bradycardia, clinically this is not always true. The cardiovascular system of these patients does not need to be disturbed during this critical postanesthetic period.

Adjuncts to the balanced anesthetic technique

Finally, two commonly used adjuncts to the balanced anesthetic technique just described will be mentioned. First, halothane is used in lieu of morphine for short cardiac cases, for induction of children who cannot tolerate a needle stick, for patients who may be allergic to morphine, and for patients with known severe bronchial asthma. Halothane also is used to supplement morphine-nitrous oxide-thiopental anesthesia.

Halothane provides simply one more “balanced agent” in the armamentarium and is extremely useful for the “fine tuning” of blood pressure, particularly in the coronary artery patient. As previously mentioned, these patients tend to become hypertensive after induction, and it is essential to prevent severe hypertension or the afterload on the heart can produce disastrous results. Halothane can do this very gracefully. The amounts used are very small, rarely exceed-
ing \( \frac{3}{4} \) MAC. Careful observation is essential, but since continuous arterial pressure monitoring is utilized, the halothane concentration can be adjusted almost literally beat by beat.

Second, the use of moderate hypothermia is employed (about 30°C). As has been known for many years, this is a good hypnotic and analgesic, but more importantly it decreases the oxygen consumption of the patient. The heart has a \( Q_{10} \) of about 2 and the liver and kidney a \( Q_{10} \) of about 3. This means that if a patient is cooled from 38°C, to 28°C, the metabolic activity of the heart is cut in half and the liver and kidney to one-third of normal. These organs, thusly, can tolerate ischemia and hypoperfusion better than they could under normothermia. The pump flow can, therefore, be decreased to a lower cardiac output—which means less mechanical damage to the blood by the pump-oxygenator. It also means the surgeon can have longer occlusion times available to him.

Such time is particularly important when he needs to clamp the aorta or a coronary artery for surgical reasons. Since hypothermia is an anesthetic in itself, this obviously reduces the amount of other anesthetic agents that one needs, thereby "poisoning" the patient less. Hypothermia also causes a shift in the dissociation curve of oxyhemoglobin to the left. The blood will then take up oxygen more readily, which allows the blood-oxygenator to completely saturate the blood at lower oxygen tensions and lower perfusion flow rates.

Hypothermia, however, is not completely without its disadvantages. Hypothermia does cause myocardial depression just as anesthetics do, although it probably does it in a safer manner by reducing overall metabolism. Practically speaking, hypothermia requires a longer rewarming time, and hence, possibly a longer time on cardiopulmonary bypass. If the timing is done properly, however, and the surgeon can gauge his speed, rewarming can be started at such time that when he is finished, the patient's body temperature is back to normal.

More importantly, however, hypothermia disturbs the rhythm, particularly by causing heart block. If the particular surgical procedure demands careful monitoring of the heart rhythm, such as when suturing a patch on a ventricular septal defect or cutting a bundle of Kent in a patient with Wolf-Parkinson-White syndrome, it is imperative that the picture not be confused by also having a hypothermic heart block. These patients are kept at normothermia.

It can be seen, therefore, that although good "balanced anesthesia" can be quite complex, it is also extremely flexible and allows more careful control of anesthesia with the extremely ill patient. The strong analgesic effects of morphine with very minimal myocardial depression have added new vistas to our concept of anesthetizing the severely ill patient.

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