The author explores the anesthetic considerations involved essentially in replacing hip joints—considerations which are equally applicable to other types of joint replacement. Emphasis is placed on the problems encountered (1) in elderly patients and (2) utilizing the polymethylmethacrylate glue necessary for these procedures.

In the past few years, there has been a tremendous change in the practice of clinical orthopedics. This change was brought about primarily by the work of John Charnley in England, who, in 1959 and 1960, began to replace the entire hip joint rather than merely the head of the femur or the acetabulum.

Charnley devised a method whereby both the acetabulum and the femoral head were replaced, one by a high-density plastic acetabulum and the other by either a vitallium or stainless steel head. Both of these components were then glued in place by the use of a type of cement known as polymethylmethacrylate. Because of the popularity of these surgical procedures, polymethylmethacrylate has since come to be known as "the glue."

On the surface, this replacement technique would seem to be a very simple procedure, however, it is anything but. It has markedly compounded the difficulties of the individual doing the anesthesia. In this article, I will be concentrating on the anesthetic considerations necessary in the total hip arthroplasty, though of course, the same considerations apply to any type of total joint replacement. Because of the complexity, as well as the duration of operative time involved in the total hip arthroplasty, many of the possible anesthetic complications would be found in this procedure.

Actually, polymethylmethacrylate is not a new compound, having been used as early as the 1940's. It has been utilized in plastic surgery, neurosurgery, dentistry, for the production of contact lenses, and so on. However, in none of these procedures, has there been an introduction of the polymethylmethacrylate into such areas as the femoral medullary cavity, where it can be very easily absorbed by the individual. As a result, there have been innumerable studies done in the past five or six years, regarding the effect of methylmethacrylate upon both the cardiovascular and respiratory systems. Obviously, at the same time, there have been a number of studies done regarding the surgical side of the procedure and its effect upon the patient's cardiovascular and respiratory systems.

As you can see, there are a number of problems that may be encountered in total joint replacement which are quite different from those found in the practice of simple clinical orthopedics. Furthermore, the type of patient who is receiving a total joint replacement is
usually not a Class I patient according to the American Society of Anesthesiologists' (ASA) grouping of physical status. We are obviously operating on patients who are older than the usual orthopedic patient, and the majority of these have either respiratory or cardiovascular complications or a combination of both prior to coming to surgery.

The first reports of sudden cardiac arrest during total hip arthroplasties appeared in the United States in 1971 and 1972. There had been reports in British literature prior to this time, however, as the British had been doing total hip arthroplasties for some years before the technique was introduced in the United States.6

The procedure of total hip arthroplasty involving the use of methylmethacrylate was evaluated at selected centers in this country from 1969 until 1971. In 1971, the Federal Drug Administration finally released methylmethacrylate for general use; and since then, total hip arthroplasties, and later total knee arthroplasties and various total joint arthroplasties have become more and more widespread in the U.S.

During the period in which methylmethacrylate was being evaluated, it became obvious that there were certain complications which were encountered in the total hip arthroplasty that might or might not be due to the methylmethacrylate itself. Consequently, a number of excellent studies on both the cardiovascular effects of methylmethacrylate and the respiratory effects of methylmethacrylate were carried out. The consensus of these studies was that the direct effect upon the respiratory system was relatively slight, but there were certain definite effects related to the use of methylmethacrylate in regard to the cardiovascular system.

Prior to going into these cardiovascular effects, I think it would be a good idea to give you a faint knowledge of the chemistry of methylmethacrylate cement. The cement itself consists of two components—a liquid and a powder—which are mixed together shortly before use. The mixture becomes hard after approximately 3-5 minutes of mixing, at which time a tremendous amount of heat is generated in the process. This heat generation, incidentally, may be as high as 80 or 90°C. and if the cement is applied when it is not quite "ripe," there may be an area of dead bone produced surrounding it.

Obviously, the mixing is very crucial, and must be carried out rapidly and properly with a definite method being employed. The use of a specific mixing method for the methylmethacrylate cement has been advocated not only by Charnley, but by other groups who have had widespread experience with it. The reason for this is quite simple: the methylmethacrylate monomer produces definite cardiovascular effects on the patient.

The basis of this acrylic cement is, of course, methylmethacrylate. The powder component consists essentially of methylmethacrylate in granular form, and benzoyl peroxide, which serves as co-activator. The liquid component consists of methylmethacrylate monomer, with the remainder being made up of water, methanol, and another co-activator. The mixing together of the liquid and the powder brings about the polymerization of the liquid monomer, which then binds together the previously polymerized powder. Obviously, there is some monomer left over, and this is what creates problems for us in anesthesia.

At this point, it should be mentioned that the glue should be mixed in an area where the vapors will be exhausted into the vacuum system of the hospital, rather than the respiratory systems of the operating room personnel. At present, we at the Mayo Medical Center are doing a number of studies regarding this, and I think it will not be too long before some type of hood or other mechanism for the removal of fumes during mixing will be found in many institutions. After all, consider one
of the toxic hazards this glue may have is on the liver.

It was noted first by Charnley, and later by others involved in total hip arthroplasties, that a transient hypotension of one degree or another often followed the application of methylmethacrylate cement to the acetabulum. Even more frequently, this hypotension was observed following the application of methylmethacrylate cement to the femoral canal. There was much speculation regarding the cause of this phenomenon, and at one time, it was felt that it might be due to a histamine release. However, the studies of Peebles and his group at the London Hospital showed rather clearly that the monomer was primarily the cause of the significant changes in blood pressure, together with an increase in heart rate and sometimes in cardiac output.7

This seemed to result from peripheral dilatation which is caused by the monomer, and obviously occurs more frequently when the methylmethacrylate cement is inserted into the femoral canal, than into any other area. Such a conclusion is only logical, as relatively high pressures can be built up when the glue is forced down into the femoral canal, resulting in emboli of air, glue, fat, or other bone marrow components. A recent study in dogs confirmed this, and showed that pressures as high as 600-800 mmHg could be built up within the femoral canal when a bolus of glue was forced into it. Obviously, such readings far exceed normal blood pressure levels, and consequently, the previously mentioned components are very easily forced into the circulation, sometimes with disastrous results.

Not all the cardiovascular changes can be blamed upon the monomer and the vasodilatation which it is known to cause. There have been innumerable cases reported in which air emboli occurred. In some cases where there has been cardiac arrest, the lungs have shown traces not only of bone marrow and fat, but also of some type of birefringent material which may or may not be methylmethacrylate. After all, this seems only logical, since the circulation from the femoral canal is quite open, and therefore, embolization is a definite possibility.

In our own institution, several of my colleagues have employed a Doppler apparatus and have definitely found evidence of air emboli in a large percentage of cases. However, we were lucky, and none of these air emboli were fatal to our patients. Later, I will detail one or two things which you can do to minimize the effect of air embolization in these cases.

Preoperative considerations

As I have mentioned previously, many of the patients who undergo total joint replacements are either ASA Category III or IV. Most of them are elderly, many of them have cardiovascular and/or respiratory disease, and still others have problems due to allied medical conditions. Consequently, a very careful medical work-up from all standpoints should be carried out prior to any total joint replacement. It is also extremely necessary to know about medications that these patients may be treated with prior to surgery and anesthesia, as well as the general status of hydration of these patients. The circulating blood volume at the time of surgery is one of the most important factors in a successful anesthetic for total joint replacement, especially when a total hip arthroplasty is to be done.

The total hip procedure, as well as the other total joint procedures to a lesser degree, carry definite morbidity and mortality. There are certain groups of patients who are at risk more than others, namely the hypertensive patient, the patient with coronary artery disease, arteriosclerosis, chronic obstructive pulmonary disease, and so on. Again, in these massive procedures, I would like to emphasize the importance not only of conducting a good medical work-up but also ensuring proper laboratory studies, not only hemoglobin and hema-
tocrit, but also electrolyte balance and the like.

In a patient who has pulmonary problems, chronic obstructive pulmonary disease, the use of a pulmonary prep with IPPB for several days prior to surgery in an effort to increase pulmonary function is certainly indicated. Obviously, pulmonary function studies, including blood gas measures, should be carried out in these patients. (I realize that I’m painting a rather nasty picture regarding anesthesia for total hip replacement, but when you’ve done as many as I have, you will certainly see the types of complications and pitfalls in which you can get yourself, unless you have a proper medical work-up.)

Another factor to consider which I did not mention specifically, is the patient who has been on steroids within the past 6-8 months, or who has had signs of hypercortisonism in the past. It is our definite feeling that these patients should be prepared with additional doses of cortisone, usually cortisone acetate, for several days prior to surgery. Actually a “cortisone prep”, as we call it, is indicated for any type of surgery in these patients—not only total joint replacement. If this is not done, you’re taking an undue risk for your patient, and from a medico-legal standpoint, have little recourse in case something bad should occur.

Another part of the patient’s preoperative condition that I have mentioned and want to consider is whether or not there is a normal circulating blood volume. The majority of these patients will have had several enemas prior to coming to surgery, and as you know, that is dehydrating. It is also important to realize that many of these patients, especially those undergoing total knee, total hip or total ankle replacement, voluntarily restrict their fluid intake, more so at night, because it is very painful to have to get up and go to the bathroom.

This last comment is only a point of common sense, and a little point that I have found to be valuable in evaluation of my patients. As far as I’m concerned, unless a patient is in congestive cardiac failure, anyone over the age of 65 who requires total joint replacement is undoubtedly dehydrated, and I treat that person as such. Obviously, a patient who has impaired renal function has to be treated differently, but I’m speaking of the general run-of-the-mill patient for total joint replacement.

Premedication for the majority of our patients consists of a narcotic, usually meperidine, plus a tranquilizer such as Phenergan®, as well as atropine. Of course, the dosage depends entirely upon the patient’s status and age and must be modified to fit each individual situation. The use of “routine” premedication, to my mind is very, very poor practice, as anyone who has been in anesthesia for any length of time well knows. Routine premedication has gotten more people into more trouble than just about anything else in the field of anesthesia.

The type of narcotic which is used must sometimes be modified because of patient allergy, however, that’s a simple matter which needs no explanation. It has been our feeling that the use of a tranquilizer of the phenothiazine group, such as Phenergan®, which is also an excellent antihistamine, has markedly reduced the incidence of minor transfusion reactions, such as urticaria, and so on. And, since all of these patients will be transfused anywhere from 1-10 or more units of whole blood, the use of an antihistamine seems to me to be quite definitely indicated.

A number of people have questioned me about the possible use of Innovar® intramuscularly as a premedicant for these patients. I can only say that it is my definite feeling that the droperidol component of Innovar® contributes markedly to generalized vasodilatation, and since these patients are going to have their positions changed during surgery, such usage really is not a good idea. For this reason, I do not advocate the use of Innovar® for premedication for these patients, especially those un-
dergoing total hip replacement, as they will be turned to the lateral position in most cases.

Vasodilatation, superimposed upon the hypovolemia which I have already mentioned, can be rather disastrous. This is especially true in elderly patients, or patients whose cardiovascular system is impaired by any type of pathology which makes it impossible for their compensatory mechanisms to work properly. So, to my mind, I see no point in compounding the problems that we are already faced with.

There are certain general principles which I feel are quite important in the care of patients having total hip arthroplasty, as well as any other type of orthopedic procedure. All patients with normal temperatures or moderately subnormal temperatures who are scheduled for orthopedic surgery are placed on a warming blanket of one sort or another, the temperature of which is usually kept between approximately 97° and 100°F. Furthermore, all fluids, as well as all blood which is administered to the patient during the procedure is warmed by passage through a blood warming coil, usually immersed in a hemokinoterm which is kept at approximately 37°C. I feel this is very important, especially in total hip arthroplasties, as all of these patients receive anywhere from 2-10 units of blood, depending upon the condition of the patient and his specific needs. It is my practice to give the patient between 500-800 ml of 5% glucose in lactated Ringer's solution prior to the surgical procedure. Obviously, this must be modified in patients who have some type of impairment of either renal function or cardiovascular function. In other words, use common sense in judgment.

If the patient is able to tolerate relatively large amounts of fluid in the preoperative period, I feel that they are indicated because of the relative hypovolemia which is present in most of these patients, especially those for total hip or total knee arthroplasty. Needless to say, the size and age of the patient also govern the amount of fluid which is given during the induction period, prior to the surgical procedure itself.

The administration of intravenous fluids and whole blood during the procedure is governed by the situation at hand. In other words, it is governed by the amount of blood loss which occurs during the procedure. It must be remembered that these patients are usually hypovolemic to start with, and that they will lose a fair amount of blood during the procedure, as well as in the immediate postoperative period. Therefore, it is our practice to keep ahead of blood loss and to allow for a loss of anywhere from 200-400 ml in the recovery room during the immediate postoperative period.

Naturally, we cannot overload patients who have cardiovascular or renal problems, but great attention must be paid to the avoidance of hypovolemia. A number of studies have indicated that...
one of the primary reasons for hypotensive episodes during the gluing of the acetabular and femoral components seems to be closely related to hypovolemia. Consequently, it is our definite feeling that we must stay ahead of blood and fluid loss throughout the procedure.

If you decide to calculate blood loss by the weighing of sponges and the measuring of blood in the suction bottles, remember that this is not an accurate method. It has been our finding in a number of studies conducted here that this method runs approximately 20% lower than the actual blood loss. This is undoubtedly due to the drying which occurs in the operating rooms where the humidity is not terribly high and where there is a constant change of air.

If you get 10-15% behind insofar as blood loss is concerned, you can be very sure of encountering a hypotensive episode at the time of the insertion of methylmethacrylate. Consequently, larger amounts of blood and fluids must be transfused than what might have been anticipated initially, so as to avoid hypotension which may be extremely deleterious to certain patients. Actually, what I want to emphasize is to use common sense in such a situation and try to stay slightly ahead of the actual surgical blood loss. This is especially important in patients who have poor cardiovascular reserve and who may not be able to handle a hypotensive episode.

Choice of anesthetic

Insofar as the choice of anesthesia is concerned for these procedures, whether you are talking about a hip arthroplasty, a total knee arthroplasty, or what have you, it is imperative that no routine be set up. Each type of anesthesia must be tailored to fit the individual patient, and there is no excuse for not doing this. Again, I primarily will discuss total hip arthroplasty because this is the most difficult of the procedures from the anesthetic standpoint. Most of the things which I will cover regarding total hips are naturally applicable to the other total joint replacements.

In our institution, all total hip arthroplasties are done with the patient in a straight lateral position, utilizing a padded steel plate approximately 12 inches in diameter placed anteriorly and posteriorly in order to keep the patient in the proper position. This is very important, as the exact angle of insertion of the prosthesis parts will determine whether or not the operation will be successful. Because of this, it is impossible for the patient to breathe spontaneously, and therefore, the individual must be intubated and respiration must be controlled.

All of the other total joint arthroplasties are done with the patient in the supine position. Some of them, such as total shoulder arthroplasty will need intubation, while others such as total fingers or total wrists usually will not. Whether or not the patient is intubated is immaterial, as ventilation must be maintained properly, either by control or assistance.

As I have already mentioned, the choice of anesthesia is very wide in these procedures and must depend on the patient's individual situation. This is especially important in patients who have renal problems, cardiovascular problems, respiratory problems, or are merely of advanced age. It must also be remembered that the majority of rheumatoid arthritics, on whom many of these procedures are carried out, often have a definite lung pathology which goes along with rheumatoid arthritis.

To further amplify, one of the most common causes of death in the rheumatoid arthritic patient under anesthesia is cervical spine subluxation. These patients often have very loose ligaments in their cervical region; and if there seems to be any involvement, it is very important that flexion and extension views of the cervical area be obtained. This is a safeguard for us in anesthesia, as we can find out whether or not there
is any subluxation with either flexion or extension. If subluxation is only on flexion we have no problems, but if it is on extension, that is another type of situation.

In our institution, the practice is to do all total hip arthroplasties under general, intratracheal anesthesia; spinal and epidurals are not used. The primary reason for this is that we feel ventilation is inadequate because of the positioning of the patient, as well as the usually present chronic lung disease. The actual choice of anesthetic agents varies from methoxyflurane, enflurane, halothane, to a combination of narcotic and muscle relaxants. What your particular choice will be is dependent upon the patient's age and general physical and medical status.

I personally do not use halothane very often, for the simple reason many of the patients coming to us have had multiple surgical procedures elsewhere in the past, of which we have no knowledge, and we prefer not to repeat halothane too frequently. The use of methoxyflurane is limited to shorter cases and patients who do not have any renal dysfunction. However, I must state that methoxyflurane is an excellent agent for some of these procedures if it is applicable to the patient. The primary reason for this is that they wake up in the recovery room pain-free because of the prolonged analgesic effect of methoxyflurane. And, considering the possibility of dislocation of the total joint arthroplasty, for example, it is nice to have the patient calm, cool, and collected in the recovery room.

**Induction and intubation**

Induction and intubation of patients undergoing total hip arthroplasty are carried out in the same manner as that for any other type of intubated patient. Induction is achieved with sodium pentothal, during the inhalation of 100% oxygen. No other inhalation agent is added until after the patient has been intubated. At this time, ventilation is either assisted or controlled as the muscle relaxants take effect. We feel that the use of a non-depolarizing muscle relaxant such as Pavulon® or Flaxedil® is indicated prior to the use of succinylcholine for the actual intubation. This not only decreases potassium release, but I can tell you from personal experience, that it decreases the fasciculation and, consequently, much of the postoperative neck and shoulder pain for the patient.

Following intubation, the patient is turned to the lateral position with the upper arm supported in an overhead arm board, which is a metal frame heavily padded with foam rubber so that no pressure can occur upon the upper arm. The lower arm is left on a padded arm board, and great care must be taken to ensure that the ulnar nerve is extremely well padded. This makes sense, not only from the patient's comfort standpoint, but from the standpoint of a question-able malpractice suit resulting if the patient comes out with ulnar palsy. When an inhalation agent is used, it is usually supplemented with small amounts of Pavulon®, since a fair amount of relaxation is necessary for the actual dislocation and relocation of the hip.

I will not detail the use of the inhalation agents, but I would like to tell you about one method which we have found to be extremely satisfactory with the fragile type of elderly patient who has marked cardiovascular and respiratory impairment. The patients are premedicated, as I have previously indicated, and the agent of choice in my practice—and I must say that this is not true of all of our staff, but it is of the majority of them—is fentanyl, supplemented by nitrous oxide, oxygen, and Pavulon®.

You will note that I said fentanyl, I did not say Innovar®. My reasoning for this is very simple. It has been my finding that when Innovar® is used in any amount, even 1-2 ml in these elderly patients, after which they are intubated and turned, the hypotension which results may be quite disastrous. This is
due to the vasodilating effect of the droperidol component of Innovar® and is not a safe thing to use in fragile patients who are going to have their positions changed under anesthesia. These patients are put to sleep with sodium pentothal and intubated in the usual way. No fentanyl is given until after the patient has been turned, and then it is given only in very small amounts, such as .5 ml or 1 ml increments as indicated by the patient's status.

In these patients, the intubation itself is usually done with Pavulon® alone, as it will be necessary to continue with the Pavulon® throughout the procedure. The usual concentration of nitrous oxide and oxygen varies slightly with each patient, but on the whole, the average concentration is 3½ liters of nitrous oxide and 1½ liters of oxygen along with the fentanyl and Pavulon®. We found that this combination promotes cardiovascular stability and have had (and here I "knock on wood") very good success using this method on our elderly patients.

At the end of the procedure, it is often necessary to reverse either the muscle relaxant or the fentanyl, or both in some situations. We use the usual combination of prostigmine and atropine for the muscle relaxant, and narcan (Naloxone®) for reversal of the fentanyl should it be necessary. In all of the total hip arthroplasties, total ankle arthroplasties, and total knee arthroplasties where there is a large amount of methylmethacrylate added to the boney surfaces, it is our practice to cut out the nitrous oxide and go on straight oxygen plus the primary inhalation agent if we are using one, or continue with merely supplemental fentanyl and/or Pavulon® as necessary if we are using a neuroleptanalgesic method.

The nitrous oxide is cut 2-3 minutes prior to the insertion of the acetabular glue and remains out of use until approximately 5 minutes after all of the glue has been put in place. This is based upon a number of studies which have showed that air embolization occurs, especially when the femoral component is added.9,10 This air embolization is markedly increased in severity of response if nitrous oxide is present. During the time when the nitrous oxide is out of the system, we tend to hyperventilate the patient with straight oxygen to a certain extent, but not too violently. This ensures the removal of most of the nitrous oxide from the body of the patient, during a time period of some 10-15 minutes.

Summary
In summary, I would like to emphasize some of the precautions which must be taken in anesthesia for total joint replacement. In the first place, it is important that the patient have a careful and a complete medical evaluation, including appropriate laboratory tests and electrocardiogram. If the patient has any severe medical conditions, these should be corrected prior to surgery.

Hypovolemia should be corrected during the induction period and should be avoided by the judicious use of intravenous fluids, especially 5% glucose in lactated Ringer's solution and whole blood throughout the procedure. The patient should be on a warming blanket, and all IV fluids and blood should be warmed. In addition, the temperature of the operating room should be kept above 70°F. Patients who become cold are apt to shiver, which markedly increases oxygen demand and cardiac output—a dangerous situation, especially in the elderly patient with poor cardiovascular reserves.

Throughout the procedure, blood pressure, pulse, electrocardiogram, and often also temperature should be monitored carefully and frequently. This is no place to take blood pressures every 15 or 20 minutes. The use of an esophageal stethoscope to monitor pulse as well as respiration is of definite value in these cases, at least in those who are intubated. The individual who is not intubated can easily be monitored by the
use of a precordial stethoscope of one type or another.

The use of a 100% oxygen concentration during the actual insertion of the glue is extremely important in the total hip, total knee, total shoulder, and total ankle arthroplasties. In these procedures, large amounts of methylmethacrylate are inserted and can easily cause problems from the cardiovascular standpoint.

As for the anesthetic technique itself, as well as the premedication, both obviously must be tailored to the individual needs of the specific patient. All of these factors are extremely important in total joint replacement, because the majority of these patients are not ASA Class I category. It has been our finding that the average ASA classification for our cases is III+, which speaks for itself. If these simple precautions are taken, the anesthetic for total joint replacement should present little or no difficulty, other than what might be anticipated because of the patient's general physical status.

REFERENCES


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