Upsala J Med Sci 79: 51–54, 1974

The Intramedullary Pressure during the Bone Marrow Trauma of Total Hip Replacement Surgery

G. HALLIN, J. MODIG, L. NORDGREN and S. OLERUD

From the Departments of Orthopaedic Surgery, Anaesthesiology and Clinical Physiology, University Hospital, Uppsala, Sweden

ABSTRACT

It is known that complications occur frequently in connection with extensive intramedullary operative procedures. The destruction of the medullary circulation is followed by a partial cortical necrosis, which certainly will diminish if the intramedullary pressure during the operation is reduced. There are also general complications with cardio-pulmonary dysfunction possibly caused by pulmonary fat embolism. The same types of complication are likely to occur in connection with total hip replacement surgery, especially during the femoral phase of the operation. In this study it was found that very high intramedullary pressures were always produced when the prosthetic stem was forced down into the femoral cavity filled with acrylic cement, while the duration of the pressure elevations after this procedure showed greater variation. The importance of the high intramedullary pressures for the extent of devascularization and cortical necrosis is discussed, as well as its possible role as an aetiologic factor in the development of general complications such as fat embolism and sudden circulatory crises.

INTRODUCTION

Intramedullary operative procedures are known to involve certain risks of complication, local as well as general. Danckwardt-Lilliestrom has shown experimentally that cortical necrosis occurs after intramedullary reaming of the rabbit tibia and dog femur, and also that high intramedullary pressure (IMP) can easily be produced (2). The extent of necrosis is significantly reduced if the rise of IMP is eliminated by a vent (3). The cortical necrosis is followed by a periosteal reaction with new bone formation (4), which is also the case in humans after intramedullary reaming and nailing. On the basis of clinical experience, it is advised that extensive intramedullary procedures should be avoided during the immediate post-traumatic phase, when the risk of general complications such as fat embolism is increased (13). This may result from release into the general circulation of medullary components such as fat and tissue thromboplastic products. This release has been shown to occur by Olerud et al. (7).

There is reason to assume that the same type of effects will follow total hip replacement operations where acrylic bone cement is used. Several authors have reported general complications such as blood pressure falls following the cementing (8, 11, 12), and also very serious reactions with cardiac arrest (9, 11). On continuous recording of the intra-arterial pressure, Phillips et al. (8) found that this pressure fell during the cementing of the femoral prosthesis, while no such effect seemed to be related to the acetabular phase of the operation. Sloof et al. (10) recently reported experiments on the dog femur, where the total filling with acrylic cement into the intramedullary cavity gave clear cortical necrosis with an abundant periosteal reaction. In addition to a considerable local thermal effect on the bone, it may be postulated that very high IMP's were obtained, contributing to the extent of necrosis.

THE PURPOSE OF THIS STUDY

It seems important to extend our knowledge concerning the variation of IMP during intramedullary operations. The purpose of this study was to record the IMP during the femoral phase of total hip replacement operations, and to correlate the variations of this pressure with the different routine procedures used in preparing the femoral shaft and cementing of the prosthetic stem.

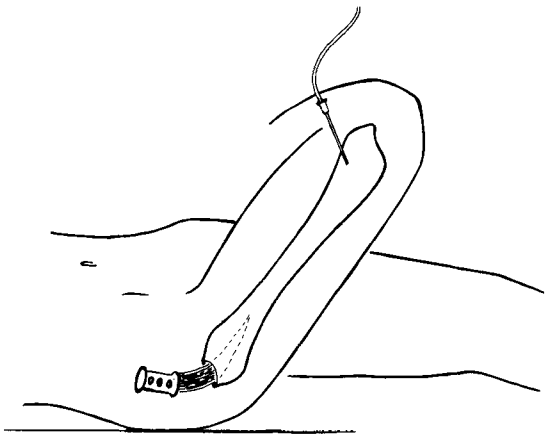

Fig. 1. The position of the cannula in the distal femur, which is externally rotated and adducted during the broaching and cementing procedure.

Simultaneously with this study the following parameters were also recorded: fibrin trapping and platelet aggregation in the lungs using ^{125}I-labelled fibrinogen and ^{51}Cr-labelled platelets monitored with an external detector, cardiac output, pulmonary vascular resistance, venous admixture in the lungs and arterial blood pressure. Fat particles, thromboplastic products, residual monomeres of the acrylic cement were also measured in pulmonary arterial blood. Some of these results are published elsewhere (5, 6).

METHODS

Measurements were made in eight patients during total hip replacement by the Charnley technique. A specially constructed cannula furnished with a screw-thread at one end was inserted medially into the distal femoral metaphysis through an anteromedial approach in the intramuscular septum. By screwing the cannula into the intramedullary cavity a steady, tight position was achieved (Fig. 1). The cannula was connected to a pressure transducer (EMT 34, Elema-Schönander, Stockholm, Sweden) by a manometer connecting tube (Portex 205, 4 feet). The pressure was registered with a direct-writing ink-jet recorder (Mingograf 34, Elema-Schönander, Stockholm, Sweden). The system was filled with physiological saline, which was allowed to stream through the cannula into the intramedullary cavity for some minutes. The base line was adjusted to the tip of the cannula with the thigh in position for reaming. The pressure recording was begun when a stable pressure with pulse-synchronous oscillations was obtained. The initial pressure value was taken as that prevailing in the cavity after the femoral neck had been transsected but prior to any further preparation of the shaft. Recording was then continued until the initial value was regained after the cementing of the prosthetic stem. The base line was checked every second minute. The highest pressure values greatly overloaded the transducer, whose nominal maximal value was 300 mmHg. The amplifier and writer were adjusted to record 100 or 800 mmHg at full signal. However, the transducers used here could not register more than 630 and 680 mmHg, respectively, and this was checked by calibration before and after every recording.

RESULTS

Fairly good agreement was found between the results from the eight patients. Fig. 2 shows the

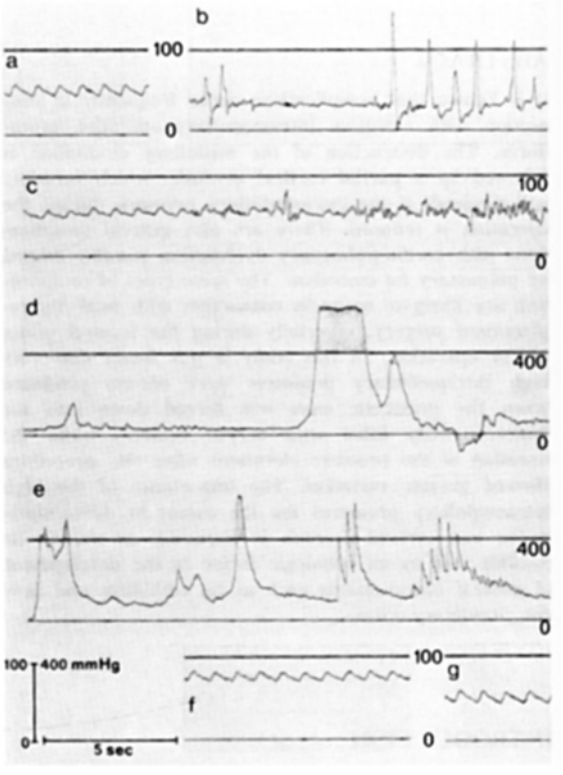

Fig. 2. (a). Initial pressure level with pulse-synchronous oscillations before preparation of the femoral shaft. *(b)* Opening and widening of the marrow cavity with tape reamers and broaches. *(c)* Filling the cavity with cement. A catheter with suction reduces the pressure during this phase. The catheter is then withdrawn. *(d)* High pressure peak when the prosthetic stem is forced down into the cement filled marrow cavity. The small vacuum effect occurs when the prosthesis-holder is removed. *(e)* Further pressure on the prosthesis gives additional peaks. To the right are seen the sharp peaks produced by hammer-blows. *(f)* The pressure tends to remain at a moderately elevated level for a while after application of the prosthesis. *(g)* The initial pressure level is regained after a delay of 1–10 min. (For further details see Table I.)

Table 1

Pat. no.	Marrow cavity pressure mmHg (Initial value)	max	Marrow cavity pressure >100 mmHg (Time in sec)	Return to initial value (after min.)
1	45	>640	6	3
2	50	>680	40	5
3	30	>630	32	10
4	40	>650	30	9
5	45	>630	4	1
6	35	>650	7	7
7	35	>650	8	10
8	50	>650	7	5

essential parts of one patient's record, depicting the different phases of the operation. Fig. 2*a* shows the basal IMP with pulse-synchronous oscillations. The moderate pressure elevations of about 100 mmHg, seen in Fig. 2*b*, occurred when the medullary cavity was opened and widened with tape reamers and broaches. When the acrylic bone cement was introduced into the femoral shaft, the cavity was always drained by a catheter to get the cavity thoroughly filled. No elevation of the pressure could be expected (Fig. 2 *c*) until the catheter was plugged with the semi-fluid plastic material. The catheter was then removed. Very high pressure peaks, always over 600 mmHg, were seen in all cases, when the prosthetic stem was forced down into the cement-filled femoral shaft (Fig. 2 *d*). The true peak values could not be recorded due to overloading of the instrument. The vacuum effect seen after the high peak occurred when the prosthesis-holder was removed. Hammer-blows gave short, sharp peaks as long as the prosthesis was moving downwards and these did not cease until the stem had stuck to the calcar region (Fig. 2 *e*).

Table I shows the variation in height and duration of the pressure elevations found in all cases. The initial values varied between 30 and 50 mmHg, and the maximal values always exceeded 600 mmHg. The duration of the pressure rise varied to a greater extent. The very high pressure recorded on insertion of the prosthetic stem had a duration of 6 to 40 sec. The pressure was then stabilized for a while at about 70 mmHg. Within 1–10 min it slowly fell to the initial level again.

The lowest pressure elevations were recorded in a patient with a very wide medullary cavity and osteoporotic bone.

DISCUSSION

This study showed that high IMP can be produced during the femoral phase of total hip replacement surgery. The pressure elevations can be related to definite phases of the operation, and with the recommended technique they seem to be a constantly occurring phenomenon.

The pressure increase would seem to be due to the piston-like effect that is induced during certain parts of the operative procedure, especially when the acrylic cement and later the prosthetic stem are pressed down into the intramedullary cavity. The force and rate of these insertions may be of importance—the greater the force applied the higher the IMP produced. The pressure-relieving catheter is probably of no value at this stage as it will be partly filled with semi-fluid plastic material.

A high pressure in the upper part of the intramedullary cavity and thereby against the cement has the advantage, that the cement is well distributed over uneven surfaces and into crevices on the inner side of the femur, which increases the possibility of stable fixation (1).

Theoretically at least a high IMP can, however, have certain deleterious effects. Crushed tissue from the intramedullary cavity and its wall on reaming can be forced out first into Haversian and Volkmanns canals and then further into the general circulation, depending on the number of open vessels available. In the former case areas of cortical tissue may be shut off from the circulation. Being necrotic the bone may later undergo resorption, thereby contributing to loosening of the prosthesis. A periosteal reaction occurring around the upper femur under certain circumstances may be an expression of such cortical necrosis (3, 10).

Furthermore, it is possible that crushed medullary components which are forced out into the general circulation by a high IMP (6, 7) may cause a general reaction (5). The magnitude of such an "injection" of medullary fat and other thromboplastic material is difficult to estimate but can probably vary within wide limits. Evacuation of the deepest part of the intramedullary cavity with a suction catheter will obviously reduce the

amount of crushed material and thereby the risk of large quantities being forced into the blood stream. The fall in blood pressure that often occurs after insertion of the femoral prosthesis may possibly be explained by this phenomenon.

It has been suggested that monomeres released from the cement may enter the blood stream and result in a fall in blood pressure. With the aim of studying this question more closely, an investigation is being made to determine the blood concentrations of fat and of monomeres of the acrylic material both during the acetabular and the femoral procedures. Furthermore, comprehensive investigations of the effects on the respiration and circulation are in progress in an attempt to elucidate the pathophysiological course of events in this type of operation (Modig et al., unpublished data).

If the necessary precautions are observed, i.e. if a pressure relieving hole or catheter is used and the femoral prosthesis is not inserted too rapidly or with too great force, complications due to excessively high IMP should no longer need to be feared.

REFERENCES

1. Charnley, J.: Acrylic cement in orthopaedic surgery, pp. 95–103. E. & S. Livingstone, Edinburgh and London, 1970.
2. Danckwardt-Lilliestrom, G.: Reaming of the medullary cavity and its effect on diaphyseal bone. Acta Orthop Scand, Suppl. *128,* 1969.
3. Danckwardt-Lilliestrom, G., Lorenzi, L. & Olerud, S.: Intracortical circulation after intramedullary reaming with reduction of pressure in the medullary cavity. J Bone Joint Surg (AM) *52:* 1390, 1970.
4. Danckwardt-Lilliestrom, G., Lorenzi, L. & Olerud, S.: Intramedullary nailing after reaming. An investigation on the nealing process in osteotomized rabbit tibias. Acta Orthop Scand, Suppl. *134,* 1970.
5. Modig, J., Olerud, S. & Malmberg, P.: Sudden pulmonary dysfunction in prosthetic hip replacement surgery. A case report. Acta Anaesthesiol Scand (in press).
6. Modig, J., Olerud, S., Malmberg, P. & Busch, C.: Medullary fat embolization during total hip replacement surgery. (A preliminary report.) Injury *5:* 161, 1973.
7. Olerud, S., Danckwardt-Lilliestrom, G. & Lorenzi, L.: Do medullary components appear in the femoral vein during the reaming of the tibia? Eur Surg Res *1:* 243, 1969.
8. Phillips, H., Cole, P. V. & Lettin, A. W. F.: Cardiovascular effect of implanted acrylic bone cement. Br Med J *3:* 460, 1971.
9. Powell, J. N., Mc Grath, P. J., Lahiri, S. K. & Hill, P.: Cardiac arrest associated with bone cement. Br Med J *3:* 326, 1970.
10. Slooff, T. J. J. H.: The influence of acrylic cement. Acta Orthop Scand *42:* 465, 1971.
11. Thomas, T. A., Sutherland, I. C. & Waterhouse, T. D.: Cold curing acrylic bone cement. Anaesthesia *26:* 298, 1971.
12. Wagner, J., Burny, F., Greens, J., De Marneffe, R. & Blaimont, P.: Etudes clinique et expérimentale sur l'action hypotensive du plastique acrylique. 11. Congrès International de Chirurgie Orthopédique, Mexico 1969, Bruxelles, 1970.
13. Wehner, W.: Die Fettembolie. VEB Verlag Volk und Gesundheit, Berlin, 1968.

Received October 18, 1973

Address for reprints:

Jan Modig
Department of Anaesthesiology
University Hospital
S-750 14 Uppsala
Sweden