INTRA-OSEOUS PHLEBOGRAPHY AND INTRAMEDULLARY PRESSURE IN THE RABBIT FEMUR

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Intra-osseous phlebography and the measurement of intramedullary pressure (IMP) have been used clinically and in experimental animals as qualitative methods of measuring blood flow in the bone. The normal phlebographic appearances in long bones are not clearly understood and the correlation between these appearances and the IMP is not known. The distal femora of 10 anaesthetised rabbits were cannulated percutaneously. The IMP was measured and phlebography performed by injecting a radio-opaque dye (Conray 280). The mean resting IMP was 33 millimetres of mercury with a range of 7 to 81 millimetres of mercury. The rate of elimination of dye from the marrow varied from less than 1 minute to 40 minutes. There was no correlation between the rate of elimination of dye and the IMP. Variation in the medullary phlebographic appearance and in the routes of drainage were noted. We conclude that the wide range of resting values for both techniques suggest that neither is a true measure of blood flow in the bone and that the results of research or clinical investigation using these techniques should be viewed with caution.

The accurate measurement of blood flow in bone is difficult. The detailed anatomy of the circulation in bones remains in doubt (Brookes 1971; De Bruyn, Breen and Thomas 1970; Lopez-Curto, Brassington and Kelly 1980) and simple methods of quantifying the blood flow do not exist. It is widely assumed that intra-osseous phlebography and the measurement of intramedullary pressure (IMP) can be used as qualitative methods of measuring blood flow in the bone.

Michelson (1968) and Shim, Hawk and Yu (1972) claim to have studied changes in bone marrow blood flow by monitoring the IMP in animals and Lemperg and Arnoldi (1978) claimed to have measured it clinically in conjunction with intra-osseous phlebography.

Alterations in the venous outflow from bones has been studied by the use of intra-osseous phlebography in fractures of long bones (Gupta, Kumar and Gupta 1980), in fractures of the femoral neck (Hulth 1958), in osteonecrosis of the femoral head (Arlet 1971) including Perthes' disease (Suramo et al. 1974), in paraplegia (Chantraine et al. 1979) and in the intra-osseous pain engorgement syndrome (Arnoldi et al. 1980).

There is, however, little available information concerning the normal phlebographic appearances in long bones and the correlation of these appearances with the intramedullary pressure either in experimental animals or man. This information is obviously required before the results of experimental use or clinical application of these techniques can be correctly interpreted.

MATERIALS AND METHODS

Ten adult female New Zealand White rabbits, anaesthetised with 30 milligrams of Nembutal per kilogram, have been studied in standardised conditions. The animals were placed supine with the hips in 45 degrees of abduction and 60 degrees of flexion. The lower femoral diaphysis was cannulated percutaneously with a 22 gauge spinal needle 40 millimetres in length and 0.4 millimetres in internal diameter (Fig. 1). The trocar was removed and the cannula connected by a semi-rigid polythene tube filled with heparinised saline to a pressure transducer (Statham P230b) and a calibrated recording system (Statham transducer readout and Bryans XY recorder). The intramedullary pressures were recorded until a stable pressure was obtained.

Intra-osseous phlebography was then performed by injecting 0.2 millilitres of Conray 280 through the cannula in 15 seconds. The

Fig. 1

Radiograph of a rabbit femur with a cannula in position distally.

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removal of dye from the marrow was recorded radiographically (Siemens Mimer 3 with Puck changer). Films were exposed at 5, 10 and 15 seconds after starting the injection, at 3, 6, 9 and 30 seconds and every minute to five after completing it. Thereafter films were exposed at five minute intervals until the dye was no longer seen.

RESULTS

Intramedullary pressure. The IMP traces showed a fluctuating pressure with variation in the amplitude between animals and between right and left femora in individual animals (Fig. 2). The range in pressures between animals was 7 to 81 millimetres of mercury with a mean of 33. There was no significant difference in the mean IMP between the right and left femora.

Intra-osseous phlebography. The clearance of dye from the marrow, that is the time taken for complete removal of the dye, was recorded and the clearance rates divided

![Fig. 2](image)

Intramedullary pressure tracings of both femora in three rabbits showing the variation of IMP and amplitude.

![Fig. 3](image)

Phlebography of rabbit femora at completion of Conray injection. Figure 3—Phlebograph showing the pool of dye around the end of the cannula, the drainage of dye along the nutrient, femoral and external iliac veins, and the filling of more than one intramedullary venous sinus. Figures 4 and 5—Phlebographs showing differences in size and shape of the pool of dye around the end of the cannula in comparison with Figure 3.

![Fig. 6](image)

Figure 6—Phlebograph showing a single central venous sinus with retrograde filling of the sinusoidal system. Figure 7—Phlebograph showing large metaphyseal venous sinuses (arrow 1) and more than one diaphyseal venous sinus (arrow 2). Figure 8—Phlebograph taken five minutes after completion of Conray injection showing the size of pool remaining around the end of the cannula and the absence of filling of marrow vessels. Figure 9—Phlebograph showing the drainage of dye via the popliteal vein only.
into four groups (Table 1). In only four rabbits were the clearance rates similar for both femora. Several variants of the phlebographic appearances were observed in the size and shape of the pool of dye at the injection site immediately after injection (Figs 3, 4 and 5) and in the pattern of filling of intramedullary vessels. Figure 3 shows more than one venous sinus in the diaphysial marrow. In one femur (Fig. 6) a single central venous sinus was seen with retrograde filling of the sinusoidal system arranged around it. In other femora dilated vessels in the metaphysis and several vessels in the diaphysial marrow were observed (Fig. 7). In one femur elimination of dye was so slow that no vessels were visualised in the marrow (Fig. 8). Variation was also seen in the pattern of venous drainage. Dye drained either proximally via the nutrient vein into the femoral and external iliac vein (Fig. 3) or distally via metaphysial veins into the popliteal vein (Fig. 9) or by both routes (Fig. 7).

The groups were combined to produce two groups with clearance rates less than and greater than five minutes so that a correlation between the two techniques could be made using an unpaired t test. No significant correlation between the rate of clearance of the dye and the IMP was found.

DISCUSSION

Intra-osseous phlebography may be considered to be a depot clearance technique of qualitative measurement of the blood flow in the bone marrow. A pool of radio-opaque dye is created around the tip of the cannula and the removal of the dye is visualised radiographically. This study has shown that the drainage of dye thus introduced into the femur of a rabbit varies both in rate and route.

The percutaneous cannulation of the bone marrow produces an unknown degree of trauma. Measurement of the intramedullary pressure is therefore the measurement of the pressure of blood in a local pool of haemorrhage from ruptured intramedullary vessels (Shim et al. 1972) and will vary according to the type and size of vessels which have been ruptured. The variation in the amplitude of the IMP reported here probably reflects this inconstant degree of trauma. This variation in amplitude has been reported in a study of normal human volunteers. The IMP was measured in the metaphysis of the distal femur and proximal tibia and in eight per cent of the bones high pressures with large pulse pressures were recorded. There was also a correlation between the amplitude of the pulse pressure and the IMP (Lemperg and Arnoldi 1978).

It has been stated that the IMP is directly related to the blood flow in the marrow (Shaw 1963; Shim et al. 1972), a low flow rate being associated with a low pressure and a high flow rate with a high pressure. In the present study, however, no correlation could be found between the pressures recorded and the rate of blood flow in the marrow as visualised by the clearance of radio-opaque dye. It would appear that in this experimental model the wide range of resting values for both techniques, and the absence of any correlation between them, suggest that neither was a true measure of blood flow in the marrow.

Using the microsphere method of measuring organ perfusion, which is generally accepted as being a more accurate method, Bouteiller et al. (1979) demonstrated that there was no correlation between blood flow and IMP in the femur of dogs. They concluded that the IMP as an isolated observation cannot accurately reflect the blood flow in the bone.

The clinical use of the measurement of IMP and intra-osseous phlebography in pathological states has been reported in a recent review (Hungerford 1980) to be more reliable and reproducible. The normal IMP in the adult human femoral and tibial metaphysis has been stated to be remarkably constant and an upper normal limit of 30 millimetres of mercury has been suggested (Ficat and Arlet 1977). One important difference between the method used in this study and that used for clinical investigation is the diameter of the cannula used. For measurement of IMP in man it is generally accepted that the cannula must be at least three millimetres in internal diameter. The size of the cannula used will determine to some extent the degree of trauma produced. The larger the cannula the greater the number and variety of vessels that may be damaged within the marrow. This is likely to reduce the variability of the values recorded by an averaging effect. However, this is not always the case, Lemperg and Arnoldi (1978) reported a range of −5 to +65 millimetres of mercury in the distal femoral and proximal tibial metaphyses in 40 normal volunteers.

The variation of the normal IMP and the phlebographic appearances described in the present study suggest that a similar variation may occur in man. The large range of normal IMP reported by Lemperg and Arnoldi (1978) would support this argument. Because intra-osseous phlebography can be painful a general anaesthetic is usually required and for this reason few normal subjects have been studied.

This study has shown that in an experimental animal, measurements of the normal IMP in the femur reveal a wide range of values. Similarly the use of
intra-osseous phlebography demonstrates a large range of clearance rates as well as variation in the medullary vessels filled and in the routes of drainage from the long bone examined. There was no correlation between the intramedullary pressures recorded and the clearance rate of Conray 280. The wide range of resting values for both techniques suggests that neither is a true measure of the blood flow in bone marrow. The results of research or clinical investigation using these techniques for this purpose should be viewed with caution.

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