Acta Orthop Scand 57, 111–114, 1986

Scintimetry of hip joint tamponade in dogs

A unilateral, continuous hip joint pressure of 50 mm Hg was established for 6 h in five puppies under general anesthesia. ^{99m}Tc-DPD scintimetry 2 and 4 weeks after tamponade showed the mean ratio between the investigated and control hip to be 1.00 and 1.01, respectively, in the epiphyses. After killing and removal of the upper femora, the same ratio was 0.94 for epiphyses and 1.02 for metaphyses. Our study did not show signs of persistent bone ischemia after tamponade below the arterial pressure.

Børge Krebs
Bjarne Nue Møller
Søren Falstie-Jensen
Finn Løve-Jepsen
Finn Taagehøj Jensen

Department of Orthopedic Surgery and Department of Nuclear Medicine, Aarhus Municipal Hospital and Institute of Experimental Clinical Research, University of Aarhus, Denmark

Correspondence: Ludvig Holbergsvej 27, DK-8230 Åbyhøj, Denmark

The epiphyseal plate forms a barrier to the blood supply to the femoral head epiphysis in children; the epiphysis is supplied solely via intracapsular, extraosseous vessels (Howe et al. 1950, Tooms & Calandruccio 1962, Chung 1976). Reports differ concerning the degree and duration of intraarticular pressure required to induce necrosis of the femoral capital epiphysis (Woodhouse 1964, Tachdjian & Grana 1968, Borgsmiller et al. 1980, Launder et al. 1981, Ganz et al. 1981, Lucht et al. 1983). These disagreements have stimulated further studies on the relationship between intraarticular pressure and the occurrence of femoral head necrosis. We studied the effect of 6 h of continuous hip joint tamponade on the femoral capital epiphysis in puppies, as indicated by ^{99m}Tc-DPD bone scintimetry after 2 and 4 weeks.

Materials and methods

Five 2½-month-old mongrel puppies weighing between 6.5 and 12.3 kg were given 0.75 ml 0.1 per cent Combelin® vet. (propionyl promazin 10 mg/ml) s.c. and anesthetized 1 h later with intermittent doses of Immobilon® vet. (etorphine hydrochloride 0.125 mg/ml, acepromazine hydrogen maleate 0.4 mg/ml) on average 0.14 ml/kg/h. Pentrexyl® (ampicillin 0.25 g) was given parenterally twice daily for 6 days. The dogs were placed in the supine position with 90° flexion, 20° abduction and 0° rotation of the hip joints.

The brachial artery was cannulated for blood pressure monitoring and blood gas analysis. The core temperature was maintained at a constant level by heat lamps. Five per cent glucose in water was transfused in a peripheral vein. The anterolateral portion of the acetabular roof was approached through a small skin incision. A 9.5-cm bone cannula (Radner®) with an outer diameter of 2 mm and an inner diameter of 1.5 mm was introduced into the hip joint through the acetabular roof, while traction was applied to the leg (Ganz et al. 1981). The position of the cannula in the joint was controlled by physiological saline at the beginning and by dissection of the joint at the end of the study. The left hip was cannulated in three and the right hip in two dogs. The contralateral hip joints were used as controls. The cannulas were attached to a heparinized pressure monitoring system via a 3-way connection and polyethylene manometer tubing (Portex®) (Elema-Schönander, EMT-34, 0–300 mm Hg; Siemens Mingograph 805). The arterial catheter was also attached to the pressure monitoring system. The intraarticular pressure was increased to 50 mm Hg and maintained at this level under constant surveillance for 6 h.

After 6 h the pressure was lowered to 0 mm Hg, and the hip joint was decannulated. The dogs were aroused by the antidote Revivon® vet. (diprenorphine hydrochloride 0.45 mg/ml).

Bone scintimetry. Two and 4 weeks after the hip joint tamponade, the joint regions were measured with the dogs in Immobilon® vet. anesthesia. Three hours prior to scintimetry, the dogs had been given 740 MBq (20 mCi) ^{99m}Tc-diphosphonate-complex (DPD-Teceos®, Hoechst, Germany) i.v. An antero-posterior projection centered over the hip joint was obtained with a gamma camera (Ohio Nuclear Sigma 410) equipped with a pin-hole collimator (Ø 5 mm) to increase maximum resolution. The gamma camera oscilloscope signals were photographed with Polaroid® film with 10^6 counts/picture. Simultaneously, digital picture registration (128 × 128 matrix) was done through a computer (Nodecrest NMS-80, V 77–600 computer system). The data were analyzed by the regions-of-interest (ROI) technique with the help of a video color monitor. ROI's were defined in relation to the femoral head epiphysis, which had been defined by previous autopsy studies. After establishment of the appropriate ROI's, counts/pixel/s were recorded for each ROI in both tamponade and control hips.

Immediately after the final scintimetry, the dogs were anesthetized and killed by an i.v. infusion of a saturated potassium chloride solution. The femur shaft was cut subtrochanterically and the proximal fragment was removed and cleaned of soft tissue. Bone scintimetry was repeated on the "clean" bones bilaterally 1/2 h after killing, and an area proximal and distal to the physeal plates (epiphysis/metaphysis) was recorded in counts/pixel/s.

Statistics. A total of 20 double determinations were made on the "clean" bone of the epiphysis and metaphysis. The methodological error, S, was calculated as follows:

$$S = \sqrt{\frac{1}{2n} \sum_{i=1}^{n} di^2},$$

where n = number of double determinations and di = the difference between corresponding double determinations. S = 0.0218 for counts/pixel/s and 0.0645 for the ratio between tamponade and control hips.

The variation coefficient was 8.71 for counts/pixel/s and 6.75 for the ratio between tamponade and control hips.

The paired *t*-test was used with a significance level of 5 per cent (Hald 1973).

Results

The arterial blood pressure was constant during the intraarticular tamponade in each dog, but varied between the dogs. The mean blood pressure was 75 (65–90) mm Hg, which was higher than the chosen tamponade pressure of 50 mm Hg. The mean values of the blood gases were paO_2 – 9.4 kPa, $paCO_2$ – 6.9 kPa, and pH – 7.4.

No significant scintigraphic differences between tamponade and control hips were seen; at 2 weeks the mean epiphyseal ratios were 1.00, and at 4 weeks 1.01 and 0.94 *in vivo* and *in vitro*, respectively.

Discussion

Rösingh & James (1969) have shown in rabbits that femoral head osteocytes die after an ischemic period of 6–8 h. Survival of bone cells is totally dependent on the remaining vascular supply after a trauma. Stein et al. (1962) have studied the circulation of the femoral head in dogs and have shown that diffusion of joint fluid to the head must have nutritive importance.

Clinically, increased intraarticular pressure is seen in pyarthrosis (Kallio & Ryöppy 1985), synovitis (Jayson & Dixon 1970, Wingstrand et al. 1985b) and hemarthrosis (Drake & Meyers 1984, Strömqvist et al. 1985). In the past 10 years, radionuclide tracers have been used to judge the vitality of the femoral head after intracapsular femoral neck fractures (D'Ambrosia et al. 1975, Greiff 1980, Greiff et al. 1980, Strömqvist 1983) and after transient synovitis of the hip in children (Wingstrand et al. 1985a). Wingstrand et al. (1985b) and Kallio & Ryöppy (1985) reported a very high (130–170 mm Hg) intraarticular pressure in children with symptoms of transient synovitis of the hip, when the hips were extended and rotated inward. However, a marked decrease was noted with the hips in 45° flexion. No information was given about the arterial blood pressure of the investigated children, but presumably the highest intraarticular pressures must have been above the mean arterial blood pressure. In experimental studies (Tachdjian & Grana 1968, Borgsmiller et al. 1980, Launder et al. 1981, Lucht et al. 1983), it has been shown that intraarticular pressures exceeding the mean arterial blood pressure are harmful to the blood supply of the femoral head.

Woodhouse (1964) demonstrated the development of femoral head necrosis in puppies after 12 h of continual intraarticular tamponade at a pressure of 50 mm Hg. He showed that even though the arterial blood supply could not be interrupted by intraarticular pressure lower than the arterial blood pressure, the effect of an intraarticular pressure increase to a level between the venous and arterial blood pressures was damaging. The resulting venous stasis led to irreversible capillary thrombosis and avascular necrosis.

We chose the joint tamponade pressure of 50 mm Hg for 6 h on the basis of Woodhouse's observations in dogs. In earlier canine studies (Launder et al. 1981, Lucht et al. 1983), the blood flow to the femoral head epiphysis was promptly reduced when the intraarticular pressure was raised above the venous pressure. We found, however, that with scintimetry no signs of avascular necrosis could be demonstrated after 2 and 4 weeks. This is in agreement with Borgsmiller et al. (1980), who found that the blood flow to the femoral head in puppies did not change with an intraarticular pressure of 50 mm Hg, but fell when the intraarticular pressure exceeded the arterial blood pressure at 100 mm Hg. Tachdjian & Grana (1968) did not find necrosis until the intraarticular pressure was greater than the arterial blood pressure.

The supine position with flexion-abduction of the hip was chosen to ensure the lowest possible intraosseous pressure (Krebs et al. 1982) and a normal intraosseous blood flow (Launder et al. 1981). The relationship between the intraarticular and the intraosseous pressure has been demonstrated by Lucht et al. (1981). Wingstrand et al. (1985b) and Kallio & Ryöppy (1985) have also demonstrated the importance of the hip position in relation to the intraarticular pressure.

Our study indicates that the time limit for the occurrence of ischemia of the femoral head epiphysis in puppies is more than 6 h of intraarticular tamponade at a pressure of 50 mm Hg. The effect of repeated, short-lasting increases in the intraarticular pressure to levels between the venous and arterial blood pressure is not known. Such a mechanism might explain the cases of ischemia of the femoral head epiphysis seen in children with intraarticular effusion due to transient synovitis, especially if combined with positions of the hip which are known to raise the intraarticular pressure (Kallio & Ryöppy 1985) above the arterial blood pressure.

References

Borgsmiller, W. K., Whitside, L. A., Goldsand, E. M. & Lange, D. R. (1980) Effect of hydrostatic pressure in the hip joint on proximal femoral epiphyseal and metaphyseal blood flow. *Proc. Orthop. Res. Soc.* **5**, 23.

Chung, M. K. (1976) The arterial supply of the developing proximal end of the human femur. *J. Bone Joint Surg.* **58**-A, 961–970.

D'Ambrosia, R. D., Riggins, R. S., Stadalnik, R. C. & De Nardo, G. L. (1975) Experience with ^{99m}Tc diphosphonate in studying vascularity of the femoral head. *Surg. Forum* **26**, 521–523.

Drake, J. K. & Meyers, M. H. (1984) Intracapsular pressure and hemarthrosis following femoral neck fractures. *Clin. Orthop. Rel. Res.* **182**, 172–176.

Ganz, R., Lüthi, U., Rahn, B. & Perren, S. M. (1981) Intraartikuläre druckerhöhung und epiphysäre Durchblutungsstörung. Ein experimentelles Untersuchungsmodell. *Orthopäde* **10**, 6–8.

Greiff, J. (1980) Determination of the vitality of the femoral head with ^{99m}Tc-Sn-pyrophosphate scintigraphy. *Acta Orthop. Scand.* **51**, 109–117.

Greiff, J., Lanng, S., Høilund-Carlsen, P. F., Karle, A. K. & Uhrenholdt, A. (1980) Early detection by ^{99m}Tc-Sn-pyrophosphate scintigraphy of femoral head necrosis following medial femoral neck fractures. *Acta Orthop. Scand.* **51**, 119–125.

Hald, A. (1973) *Statistiske metoder.* pp. 242–245, 299–303, Akademisk forlag, Copenhagen.

Howe, W. W., Lacey, T. & Schwartz, R. P. (1950) A study of the gross anatomy of the arteries supplying the proximal portion of the femur and the acetabulum. *J. Bone Joint Surg.* **32**-A, 856–866.

Jayson, M. I. V. & Dixon, S. J. (1970) Intraarticular pressure in rheumatoid arthritis of the knee. *Ann. Rheum. Dis.* **29**, 261–265.

Kallio, P. & Ryöppy, S. (1985) Hyperpressure in juvenile hip disease. *Acta Orthop. Scand.* **56**, 211–214.

Krebs, B., Paulsen, P. K., Lucht, U. & Djurhuus, J. C. (1982) Influence of the hip joint position on the intraosseous pressures in the juxta-articular bones. *Eur. Surg. Res.* **14**, 440–446.

Launder, W. J., Hungerford, D. S. & Jones, L. H. (1981) Hemodynamics of the femoral head. *J. Bone Joint Surg.* **63**-A, 442–448.

Lucht, U., Djurhuus, J. C., Sørensen, S. S., Bünger, C. & Sneppen, O. (1981) The relationship between increasing intraarticular pressures and intraosseous pressures in the juxta-articular bones. *Acta Orthop. Scand.* **52**, 491–495.

Lucht, U., Bünger, C., Krebs, B., Hjermind, J. & Bülow, J. (1983) Blood flow in the juvenile hip in relation to changes of the intraarticular pressure. An experimental investigation in dogs. *Acta Orthop. Scand.* **54**, 182–187.

Rösingh, G. E. & James, J. (1969) Early phases of avascular necrosis of the femoral head in rabbits. *J. Bone Joint Surg.* **51**-B, 165–174.

Stein, J., Beller, M. L. & Nedwich, A. (1962) Circulation of the femoral head (end-organ) in dogs *J. Bone Joint Surg.* **44**-A, 1493–1494.

Strömqvist, B. (1983) Femoral head vitality after intracapsular hip fracture. *Acta Orthop. Scand.* Suppl. 200, 11–60.

Strömqvist, B., Wingstrand, H., Egund, N., Carlin, N.-O., Gustafson, T., Herrlin, K., Nilsson, L. T., Thorngren, K.-G. & Önnerfält, R. (1985) Traumatic hip joint tamponade. Two cases with femoral head ischaemia. *Acta Orthop. Scand.* **56**, 81–85.

Tachdjian, M. O. & Grana, L. (1968) Response of the hip joint to increased intraarticular hydrostatic pressure. *Clin. Orthop.* **61**, 199–212.

Tooms, R. E. & Calandruccio, R. A. (1962) Experimental production of avascular necrosis of the capital femoral epiphysis by extreme internal rotation of the hip. Read at the *Eighth Annual Meeting Orthopedic Research Society, Chicago, January.*

Wingstrand, H., Bauer, G. C. H., Brismar, J., Carlin, N. O., Pettersson, H. & Sundén, G. (1985a) Transient ischaemia of the proximal femoral epiphysis in the child. Interpretation of bone scintimetry for diagnosis in hip pain. *Acta Orthop. Scand.* **56**, 197–203.

Wingstrand, H., Egund, N., Carlin, N. O., Forsberg, L., Gustafson, T. & Sundén, G. (1985b) Intracapsular pressure in transient synovitis of the hip. *Acta Orthop. Scand.* **56**, 204–210.

Woodhouse, C. F. (1964) Dynamic influences of vascular occlusion affecting the development of avascular necrosis of the femoral head. *Clin. Orthop.* **32**, 119–129.