PERIPHERAL JOINT IMAGING: VARIATIONS

IN NORMAL CHILDREN

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Imaging of peripheral joints is a simple and valuable technique for evaluating joint disease in adults (1–12). It has been shown to be a sensitive index of inflammatory activity, occasionally revealing synovitis before the roentgenogram, laboratory studies, or even physical examination is positive (1–13). These studies document the presence and location of inflamed synovium and reflect progressive activity or remission in patients with proven joint disease.

Since 1967 we have studied over 500 patients using $^{99m}$Tc-pertechnetate ($^{99m}$TcO$_{4}^{-}$) with a scintillation camera. In our experience with joint imaging we noticed that there are areas of increased localization of radiopharmaceutical in children which are not seen in adults and which are not related to any particular symptomatology. These localizations correspond closely to the areas of bone growth and ossification in the joints under evaluation and appear to be normal variations. Our purpose is to publish these findings so that a better understanding of the normal localization of radiopharmaceutical in the joints of children will be obtained.

MATERIALS AND METHODS

Joint imaging has been used in the evaluation of children with joint pains and proven joint disease at our institution since 1967. The present study comprises 27 children with normal joint scans who were referred to our department for evaluation of some other problem (i.e., brain scan, renal studies, thyroid scanning). Various joint areas were examined at the time of their scheduled study. In all patients the wrists and knees were evaluated. In 17 patients the elbows, ankles, shoulders, and feet were also evaluated. None of the children studied has subsequently developed any disease related to the skeletal system.

Several of these patients were studied because of “joint pains”, but none of these, despite extensive clinical and laboratory examinations, has any proven joint disease. There were 16 girls and 11 boys whose ages ranged from 18 months to 17 years.

Twenty-one patients were studied with $^{99m}$Tc-per-technetate. Seven studies were performed using $^{99m}$Tc-diethylenetriamine pentaacetic acid (DTPA). One patient was subject to two examinations on consecutive days and both radiopharmaceuticals were employed. In an effort to evaluate the best time after the administration of the isotope for obtaining an image, a number of patients were studied with sequential scans performed at 5 min, 30 min, and as late as 1½–2 hr after the injection of tracer material.

The thyroid gland was blocked with Lugol’s solution before the study. A dose of 15 mCi $^{99m}$TcO$_{4}^{-}$/1.73 mCi $^{99m}$TcO$_{4}^{-}$/1.73 M$^{2}$ was given intravenously, and joint imaging was started at 5 min postinjection. Views of the joints were taken from the right and then from the left so that the two images corresponded closely in time. A scintillation camera was used with a 4,000-hole, low-energy collimator. The spectrometer range was set for $^{99m}$Tc, and a 15% window was used. For knee and hand images 70,000 counts were accumulated and the time was recorded. The contralateral joint was counted for a similar time. Only 50,000 counts were accumulated for elbows and ankles. One-minute exposures were used for the shoulders.

Each joint area was studied individually except in the case of very small children. In these cases scintiphotographs of the lower extremity would include both the knees and ankles. The wrists and elbows of infants could also be imaged in a single scintiphoto. Efforts were made to keep the positions at the time of each study as identical as possible. The dorsal surfaces of the hands and the plantar...
surfaces of the feet were examined. The ankles and elbows were studied only from the lateral position. Anterior views of the shoulders were obtained. The knees were viewed from both the anterior and lateral projection. Care was taken to have each joint area well centered with adequate shielding to prevent scattered radiation to other areas. Only peripheral joints were evaluated because of their relative ease of positioning even with small children and because the high body background obscures joint detail in the more proximal joints. Hips were not included in the study, and only 11 views of shoulders were obtained.

RESULTS

The study demonstrated consistent localizations in areas of new bone growth (the metaphyseal and epiphyseal regions in the long bones, and the ossification centers in the small bones of the wrists and feet). In addition, the sequential scanning in several patients indicated that the optimal time for imaging was between 5 and 30–45 min after injection of the tracer material.

Wrist and hands. The wrists and hands of children showed an interesting pattern of localization in the region of the carpal bones. This area of localization was one of the most consistent findings in all of the normal children studied. An inexperienced interpreter of these studies would suspect disease in these regions because the pattern is similar to that seen in rheumatoid arthritis; however, the degree of localization is usually less than is seen with inflammatory lesions of the synovium. A number of children demonstrated positive areas of isotope concentration in the regions of the metacarpal heads, most commonly the second, third, and fourth metacarpals. These localizations are probably related to the normal epiphysis of the distal metacarpal and again are differentiated from pathological localizations by the degree of intensity of isotope concentration and the anatomic position. Only rarely was a distinct linear localization observed in a region corresponding to the distal radial epiphysis.

Elbows. The elbows are one of the more difficult areas for interpretation (Fig. 2). Lateral scintiphotos of the elbow were studied. Increase in activity in the region of the epiphyses was quite diffuse, probably because of the relatively large bulk of muscle and soft tissue overlying bony structures in this region. A diffuse globular area at the apex of the elbow was often identified and is probably related to the epiphyses in the distal humerus or olecranon. This localization was not well demonstrated in all patients.

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Its appearance was not related to time of joint imaging and when noted was always bilateral and symmetrical. The humerus appeared as an area of decreased $^{99m}$TcO$_4^-$ localization, but this pattern was not seen in the area occupied by the radius and ulna probably because of bone size and overlying tissue vascularity.

**Shoulders.** The anterior view scintiphotos of the shoulder demonstrated a homogeneous concentration of isotope in the region of the proximal humerus (Fig. 3). The localization in these epiphyses was not as discreet as in the lower extremity for several reasons. The high-body background in the shoulder area allows considerable scatter, and a relatively large bulk of muscle overlies the proximal humerus. These factors contribute to the poor localization in the proximal humeral epiphyses. This localization in the shoulder region is seen as late as in patients 13 years of age but is quite indistinct by that age. Brachial vessels are usually seen on this view.

**Knees.** Scintiphographs of the knees were obtained in both the anterior and lateral positions (Fig. 4). In the first decade one can easily identify linear areas of localization corresponding to the distal femoral epiphyses and proximal tibial epiphyses on the anterior view. The areas occupied by femur, tibia, and patella appear as negative areas of $^{99m}$TcO$_4^-$ localization. If scintiphographs are obtained within 30 min of the tracer injection, a distinct area of virtually no radioactivity can be seen which corresponds to knee joints in both the anterior and lateral views. The scintiphographs obtained after this time show increasing concentration in the joint space and some decreasing definition of the epiphyseal areas (Fig. 5). These localizations are horizontal and do not appear to be related in any way to the vascular bundles in the posterior portion of the popliteal region. Even with extremely delayed scans, at no time was the concentration in the joint space equal in intensity to that seen in pathological conditions involving the synovial membrane of the knee. The localization in the epiphyseal regions is often markedly increased over the activity in the popliteal vascular bundle. It is intense enough to be confused with a pathological condition except that its distribution is above and below the actual joint space and it has an extremely linear appearance. Epiphyseal localization was identified in the scintiphographs of the knees in male children as late as 17 years of age. As would be expected from known growth patterns, epiphyseal localization in the bones about the knee was quite faint in older girls and was not seen in any girls over 16 years of age.

**Ankles.** On the lateral view of the ankle a consistent localization in the region of the distal tibial
FIG. 6. Normal ankles. Linear localization in distal tibia is demonstrated. There is no significant localization within ankle joint in normal. Note activity in foot of 2-year-old in anterior tarsal area.

FIG. 7. Normal ankles. Distal tibia, calcaneus, and talus appear as more negative areas of localization. In a few patients, crescent-shaped area of increased $^{99m}$TcO$_4^-$ localization on posterior aspect of calcaneus was seen as demonstrated in 15-year-old above.

Isotope form. The areas of isotope localization described above were imaged with both the pertechnetate and DPTA forms of $^{99m}$Tc. We were unable to detect any significant difference of localization related to the form of the isotope used. With both forms of technetium the scintiphotos obtained within 15 min of the injection of tracer showed concentration in the vascular bundles of the regions examined—the popliteal vessels at the knee, anterior tibial vessels at the ankle, and subclavian vessels in the region of the shoulder. The images obtained at 30 min showed much less localization in these vascular areas, and images obtained 1 hr after injection rarely demonstrated significant isotope concentration in the vascular bundles.

Shortly after the injection of the radiopharmaceutical, localization in the epiphyseal areas described previously could be identified. In the joints examined within 30 min of injection, the joint space and large skeletal structures were easily visualized as negative, or cold areas, showing relatively small metaphysis or epiphysis was readily seen in all children from ages 1½ through 10 years (Fig. 6). This localization varied from a rather globular appearance to a distinct horizontal line just above the region of the tarsal bones. After the first decade there was a gradual decrease in the intensity of this localization, and it was no longer evident in any of our patients after the age of 15. The appearance of the ankles after that age was identical to that seen in adults. Distal tibia, calcaneus, and talus appeared as negative areas of $^{99m}$TcO$_4^-$ localization. In several patients near the middle of the first decade a crescent-shaped area of increased $^{99m}$TcO$_4^-$ localization on the posterior aspect of the calcaneus can be demonstrated (Fig. 7). This activity is quite distinct from the normal vascular bundles which are seen in the region of the ankle and is probably related to the calcaneal epiphysis. It is not seen in all children. We have no explanation for its absence in some apparently normal children.

Feet. In a few individuals the plantar surface of the feet was examined (Fig. 8). The localization of isotope appeared to be concentrated in the tarsal area and had a diffuse, globular appearance similar to that seen in the carpal bones. Similar to the small bones in the hand, these localizations were identified in children as late as 15 years of age.
amounts of tracer localization. As the time elapsed after the 30-min postinjection study, increasing accumulation in the regions of the joint space could be identified (Figs. 5 and 9). All areas of epiphyseal or ossification center localization could be well documented and identified as normal variants in images obtained within 45 min of the injection time. Scintiphotographs obtained after this time showed localization in the epiphyseal regions, but these were less distinct because of the increasing localization in the joint space adjacent to these areas.

DISCUSSION

Joint imaging has proven to be a useful tool in adults for detection of synovitis, documentation of the pattern of synovitis, following inflammatory joint disease, and evaluation of joint pain. Weiss, et al (1) in 1965 suggested the technique of external joint imaging following the intravenous administration of $^{131}$I-tagged human serum albumin (HSA) as a method of evaluating synovial inflammation in patients with rheumatoid arthritis. They reported that clinically normal knee joints showed no localization of the radiopharmaceutical higher than the amounts found in the soft tissues and the vascular bed in the surrounding area, whereas most rheumatoid knee joints showed higher than normal localization. Similar joint localization patterns have been described using $^{99m}$Tc-human serum albumin and $^{99m}$Tc-pertechnetate (2,4,7).

Glickman, Sholkoff, and Gilbert (12) have aptly described the normal distribution of $^{99m}$TcO$_4^-$ in the joint areas in adults. Joint imaging in the pediatric population is still rather unexplored. The main difference noted in our studies was the appearance of areas of increased $^{99m}$TcO$_4^-$ in the epiphyseal regions of growing children. These were best seen in areas of rapid growth. Presumably this localization is the result of an increased blood flow to this area and, since this localization disappears when the epiphyses close, one must assume this is a normal phenomenon.

Epiphyseal localization does not interfere with joint imaging as a diagnostic test. Pathologic localization of the $^{99m}$Tc radiopharmaceuticals is readily identified in the presence of epiphyseal activity (13). The mechanism of localization of these radiopharmaceuticals in joints seems twofold. St. Onge, et al (14) demonstrated an increased synovial membrane blood flow of three times normal in patients with rheumatoid arthritis using $^{133}$Xe. Whaley, et al (5) suggested that the percentage of the dose taken up in the synovial membrane correlated with the degree of inflammation and was a reflection of the vascularity of the synovial membrane and other joint tissues. They felt that diffusion was not as important as blood flow as a mechanism of localization and found that the activity in joint fluid did not exceed 50% of that in blood in patients with rheumatoid arthritis. McCarty, Poley, and Collins (10), however, were able to demonstrate some decrease of activity following joint aspiration suggesting that extravasation into the joint fluid was a factor. It is likely that both blood flow and diffusion are important factors in the distribution of these radiopharmaceuticals in and about the joints.

The value of joint imaging is definitely determined by the timing as shown. Early studies with $^{99m}$TcO$_4^-$ are more informative; in pathological conditions the early joint images will demonstrate the pathology better than later images (9,13). An attempt should be made to complete the study by 30–45 min if $^{99m}$TcO$_4^-$ is used. If excessive time elapses between injection of $^{99m}$TcO$_4^-$ and joint imaging, the degree of localization in normal joints may increase. This same phenomenon was reported by Cohen and Lober (15) during their evaluation of synovial-seeking radiopharmaceuticals. It was their impression that $^{99m}$TcO$_4^-$ was not the agent of choice for joint imaging completed 1 hr after injection because of these false positive scans. If joint imaging can be completed prior to 45 min following injection of $^{99m}$TcO$_4^-$ using a scintillation camera, we feel pertechnetate is a satisfactory joint-imaging agent. Delayed localization in the joints has not been as much of a problem with $^{99m}$Tc-DTPA. However, because of renal clearance of this agent, the time required to complete the joint study is longer even if scanning is started immediately after injection.

SUMMARY

Peripheral joint imaging in children, using the radiopharmaceuticals $^{99m}$TcO$_4^-$ and $^{99m}$Tc-DTPA, reveals areas of unusual isotope localization not seen in adults. These areas correspond to regions of new
bone growth. Factors to be considered in evaluating
the pediatric joint study include the age of patient,
the time when the study was completed after injection
of the radiopharmaceutical, and the actual radiopharmaceutical used in the study.

REFERENCES


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