Short communication

Response of Charcot's arthropathy to contact casting: assessment by quantitative techniques

M. McGill¹, L. Molyneaux², T. Bolton², K. Ioannou³, R. Uren³, D. K. Yue¹

¹ Department of Medicine, University of Sydney, Sydney, Australia

² Diabetes Centre, Royal Prince Alfred Hospital, University of Sydney, Sydney, Australia

³ Advanced Nuclear Medicine Services, University of Sydney, Sydney, Australia

Abstract

Aims/hypothesis. This study used two different methods of quantitative bone scanning to study the relation between activity of Charcot's arthropathy and clinical variables over 12 months.

Methods. Skin temperature of affected and unaffected feet was measured at baseline and every 3 months for 12 months in 17 subjects. Eight subjects underwent a three-phase quantitative bone scan at baseline and 3 monthly for 12 months. Bone isotope uptake in a standard rectangular area over the foot and tibia was analysed by the bilateral scan method (the ratio of isotope uptake of affected and unaffected feet) and the unilateral scan method (the ratio of isotope uptake of affected foot and ipsilateral tibia). The affected foot was placed in a contact cast for an average of 8 months.

Results. At presentation the affected foot was hotter than the unaffected foot but the temperature became progressively cooler over 12 months. Median isotope

uptake in the affected foot was 2.1 % of the injected dose (interquartile range, IQR 1.9–3.0). In both scanning methods the ratio of uptake decreased after casting but at 12 months the affected foot still had more isotope uptake. There was a strong correlation between temperature difference and the ratio of uptake in the bilateral scan method ($r = 0.90$; $p < 0.0001$) but when using the unilateral scan method this relation was not significant ($r = 0.1$; $p = 0.6$). A strong relation existed between perfusion of the affected foot in the dynamic phase and isotope uptake in the delayed phase of the scans ($r = 0.92$; $p < 0.0001$).

Conclusion/interpretation. Bone activity and skin temperature of Charcot's arthropathy can be measured quantitatively and both improve over 12 months with contact casting. There is a strong relation between perfusion and disease activity in this condition. [Diabetologia (2000) 43:481–484]

Keywords Complications, neuropathy, foot, radionuclide scan, podiatry.

The assessment and management of Charcot's arthropathy has been limited by the lack of sensitive and objective assessment methods with clinical observation and radiography forming the mainstays of evaluation [1–7]. As a result, although rest and contact casting are accepted methods of treatment there is little objective data on their impact on the disease.

Radionuclide scanning has been used to compare the affected foot of patients with or without Charcot's arthropathy [8]. We used two different methods of quantitative bone scanning to study the relationship between activity of Charcot's arthropathy and clinical variables over 12 months during which patients received standard treatment of rest and contact casting.

Received: 11 October 1999 and in revised form: 1 December 1999

Corresponding author: M. McGill, Diabetes Centre, Royal Prince Alfred Hospital, Sydney, Australia, 2050

Subjects and methods

Subjects. Patients ($n = 17$) with acute unilateral Charcot's arthropathy were treated with rest and application of contact cast and monitored by temperature measurement. In a subset

of eight patients, quantitative bone scans were done every 3 months for 12 months and the contact cast was applied immediately after the baseline scan. Acute Charcot's arthropathy was diagnosed by usual clinical criteria of abrupt onset of a hot and swollen foot supported by appropriate bone scan, white cell scan and radiological findings in the absence of other diseases such as gout, arthritis or infection which can produce a similar clinical picture.

Skin temperature. Skin temperature of the affected foot was measured at the hottest point by a hand-held infrared temperature scanner (Dermatemp, Exergen Corporation, Mass., USA). Thereafter, the temperature of the affected and control feet was measured at the same location every 3 months during the study. The mean between subjects, and observers, CV for the temperature measurements taken on the same day was 5.2%.

Quantitative bone scanning. We injected 40 MBq of $^{99m}\text{TcEHDP}$ intravenously, delivering only 11 MRems per scan. A standard of 10–20 MBq was used to decay correct all counts. All images were taken using a low energy all purpose collimator. Images for the dynamic phase (which measures blood flow) were taken in 10 s frames for 20 frames; images for the blood pool phase were taken immediately afterwards using a 400 s acquisition. Images for the delayed phase (which measures bone uptake) were taken at 2 h after the injection for 400 s.

Isotope uptake in a standardised rectangular area over the affected foot was quantified for each of the three phases. As controls, isotope uptake was also measured over the identical area of the contralateral foot and over the ipsilateral tibia immediately below the knee. Data was analysed by the bilateral scan method (the ratio of isotope uptake of affected and unaffected foot) and the unilateral scan method (the ratio of isotope uptake of affected foot and ipsilateral tibia). Ratios were obtained using background-corrected counts. The uptake was calculated for both feet using the following formulas:

Injected activity gamma camera counts ($C\delta d$) = standard gamma camera counts $\times 4 \times$ dose injected (MBq)/ standard dose (MBq) before injection

Bone counts = bone counts over region of interest – (area of region of interest over foot in pixels $\times$ mean background counts)

Bone uptake = (bone counts / $C\delta d$) $\times 100$

Contact casting. The affected foot was placed in a contact cast after the baseline scan until the skin temperature of the affected foot had reduced to within 2°C of the control foot (an average of 8 months).

Statistical method. Statistical analysis was done using the NCSS97 (Number Cruncher Statistical System) software (Dr. J.L. Hintze, NCSS, Kaysville, Utah, USA). Parametric tests were used for comparison. Results were expressed as median with inter-quartile range (IQR). Categorical data were expressed as a proportion. Mann-Whitney U and Wilcoxon's signed-rank test were used for comparison of continuous variables. The relation between the continuous variables was assessed by Spearman's correlation. Significance was accepted at the $p = 0.05$ level.

Results

The clinical characteristics of the 17 subjects and the subset of 8 subjects who underwent scanning were similar; median age 58.5 years (IQR 53.5–65.5), duration of diabetes 13.5 years (IQR 7.0–19.5), Type II (non-insulin-dependent) diabetes mellitus 75% and Anglo-celtic origin 87.5%.

At presentation, the affected foot was 3.3°C (2.4 – 4.7) hotter than the unaffected foot. The temperature difference became progressively smaller with casting during the 12 months follow-up. After 6 months it was significantly less than at baseline 1.3°C (0.5 – 1.9) and by 12 months there was only 0.8°C (0.3 – 1.6) difference between the affected and control feet.

The median isotope uptake in the affected foot at baseline was 2.1% of the injected dose (IQ 1.9–3.0) and this fell gradually over 12 months. Using the bilateral scan method, the ratio of uptake in the affected:unaffected foot fell progressively over time and again became different from baseline from the sixth month onwards. The ratio of 1.3 (IQ 1–1.4) at the twelfth month indicated, however, that the affected foot still had 30% more isotopic uptake. Using the unilateral scan method, the ratio of foot:tibia isotope uptake on the affected side also fell after casting (Fig. 1).

There was a strong correlation ($r = 0.90$, $p < 0.0001$) between temperature difference and the ratio of isotope uptake in the affected:unaffected feet (Fig. 2). Removal of the patient who had the highest temperature and isotope uptake, weakened, however, the relation although it remained statistically significant ($r = 0.60$, $p < 0.0001$). No relation was found using the unilateral scan method ($r = 0.1$, $p = 0.6$). There was a strong relation between the perfusion of the affected foot in the dynamic phase and the isotope uptake in the delayed phase of the bone scans (Fig. 2) ($r = 0.92$, $p < 0.0001$).

Discussion

The clinical course of Charcot's arthropathy is fairly well described but due to a lack of objective indices, it is difficult to document it in quantitative terms. Likewise it has been difficult to study its aetiology and responses to various treatment modalities. For these reasons we examined methods of quantifying the activity of Charcot's arthropathy and its progress during contact cast treatment. Skin temperature was measured quantitatively and compared with quantitative bone scanning. This possibility has been explored previously in a cross-sectional study [8]. We extended this by studying absolute bone isotope uptake over time and also by taking advantage of the contralateral control foot to provide more precise comparison.

Fig.1A, B. The ratio of bone isotope uptake between **A** the affected and unaffected feet in the bilateral scan method (* different to baseline $p < 0.05$ and **B** the affected foot and tibia in the unilateral scan method (* different to normal $p < 0.005$, + different to baseline $p < 0.04$; tibia:foot ratio for affected foot; - - - tibia:foot ratio for unaffected foot)

Quantitative measurement of skin temperature of the affected and unaffected feet indeed substantiates the clinical impression that the affected limb is hotter at presentation and continued to decline for 12 months with casting. This trend agrees with the reduction in isotope uptake quantified by either of the two methods. In the bilateral scan method, there is an excellent correlation between differences in temperature and differences in isotope uptake between the normal and abnormal feet. Although the correlation was stronger in the higher range of temperature and isotope uptake, it remained statistically significant in the lower range. In the unilateral scan method, the correlation with temperature difference is much poorer and not statistically significant if the one patient with extremely severe disease is removed

Fig.2A, B. The relation between **A** temperature difference and the ratio of bone isotope uptake between affected and unaffected feet ($r = 0.90$) and **B** isotopic activities in the blood flow phase and bone uptake phase ($r = 0.92$) ○ data from patient M, $p = 0.0001$

from consideration. We feel that both measurements of temperature and the bilateral method of quantifying bone isotope uptake should be used as indices in monitoring activities of Charcot's arthropathy.

An excellent correlation was noted between perfusion of the affected limb (measured by the dynamic phase isotope count) and osteoblastic activity (measured by the delayed phase isotope count). This supports the commonly held notion that blood flow is increased in acute Charcot's arthropathy and could have a pathogenic role. This relation could also explain the good correlation between skin temperature and bone isotope uptake as skin temperature is substantially regulated by blood flow. Note that with casting, blood flow and bone disease activity fall in parallel, again indicating that the two processes are likely to be intimately related. It could not, however, be determined from our experiment whether the primary event in our patients is a reduction in blood

flow with secondary decrease in bone disease activity or the reverse scenario (ie. the decrease in bone disease activity which secondarily leads to reduction in blood flow).

Our study has provided quantitative information on the behaviour of acute Charcot' Arthropathy over 12 months. Because every patient had a contact cast applied to preserve foot shape, our results do not to reflect the natural course of this disease. It would not, however, be possible ethically to allocate patients at random to no casting because it is the accepted method of treatment for this dangerous condition. Developing better methods of monitoring its activity would enable scientific evaluation of therapeutic interventions.

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