The Ulster Medical Journal, Volume 61, No. 2, pp. 151 – 156, October 1992.

The Belfast hip screener: from infancy to maturity

W G Kernohan, Bernadette P Trainor, Pauline E Haugh, Adrienne F Johnston, R A B Mollan

Accepted 21 September 1992.

SUMMARY

Hip dislocation remains the most significant childhood orthopaedic abnormality despite the efforts of neonatal screening, first described in 1910. A new method of enhancing the performance of screening, the Belfast hip screener, is a non-invasive device developed to detect and interpret the vibrations ("clicks" and "clunks") *which are emitted as the hips are physically tested. A progress report is presented covering ten years' work from early records made with tape recorders to modern methods of digital signal processing.*

INTRODUCTION

Developmental dislocation of the hip is a term covering a spectrum of childhood hip disease ranging from instability at birth to established dislocation. In Northern Ireland the disease affects two infants per thousand live births, though the incidence varies with sex, family history and environmental factors such as posture in utero, delivery, and nursing habits.[1, 2, 3] Formerly called 'congenital', this term should be dropped from common usage as it excludes the possibility of late development.[4, 5] In developmental hip dislocation the head of the femur while reducible is unstable, or it lies outside its normal position which is within the acetabulum. Early detection and immediate treatment of the condition in an abduction splint generally result in normal development without admission to hospital.[1, 6] However, almost 50% of cases present late (beyond three months of age), necessitating extensive treatment, including traction and repeated surgical intervention, which does not guarantee a successful outcome.[7]

The distinguished French orthopaedic surgeon Dr Pierre le Damany was among the first to describe a physical test to achieve early diagnosis.[8] He developed the clinical examination of the neonatal hip by two manoeuvres. The first was simply

Department of Orthopaedic Surgery, The Queen's University of Belfast, Musgrave Park Hospital, Belfast BT9 7JB.

W G Kernohan, PhD, Lecturer.

R A B Mollan, MD, FRCS, FRCSI, Professor of Orthopaedic Surgery.

Musgrave Park Hospital, Belfast BT9 7JB.

Bernadette P Trainor, SRN, Research Staff Nurse.

Pauline E Haugh, SRN, Research Staff Nurse.

Adrienne F Johnston, RGN, Research Staff Nurse.

Correspondence to Dr Kernohan.

a modification of the 'telescoping' manipulation in which the femur is moved along its length without rotation. The second described the exact placing of the examining hand and the stabilisation of the pelvis, as well as the control of the greater trochanter by the middle finger, while the femoral head was gently lifted in an out of the acetabulum (Figs 1, 2). Notice his emphasis on positioning and the description of a *"ressaut"* (spring-back) when the hip reduces. In 1935 Ortolani[9] devised a similar test to detect dislocated hips noting audible and palpable vibration events during testing. Barlow,[10] in 1962 amended this manoeuvre so that those hips that dislocate can be detected, though, in fact, he added little to the tests described by le Damany.

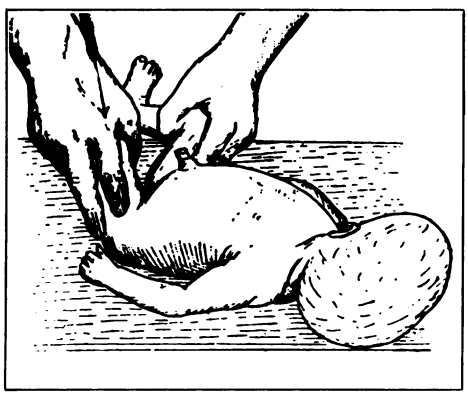

Fig 1. Position des mains de l'opérateur et position de l'enfant dans la recherche de la hanche subluxable (le Damany, 1910).

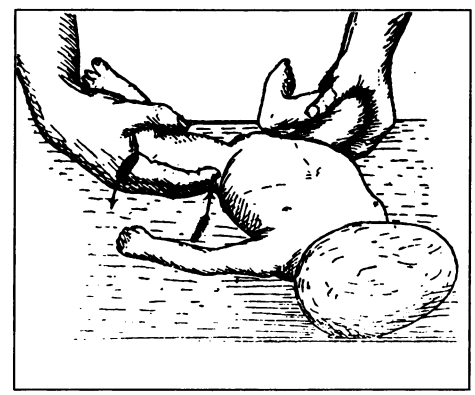

Fig 2. En portant la cuisse dans la position de flexion-abduction, la subluxation se reduit avec un ressaut (le Damany, 1910).

PILOT STUDIES

The use of miniature accelerometers to detect neonatal hip vibration during screening for developmental dislocation of the hip has been carried out in Belfast since 1980.[11] The original vibration technique based on analogue amplifiers and tape recording allowed these tests to be analysed in terms of detection and interpretation.[12] The first trial of the system was carried out on children referred to a research clinic.[13, 14] The study involved selected groups totalling 306 selected neonates, referred for vibration arthrometry. The largest subset (N = 217), was already diagnosed with 'clicky' hips. On testing, a total of over 600 vibration episodes were captured for analysis. To be certain of the clinical outcome the children underwent a long follow-up with several attendances over a four year period. Abnormal vibrations indicating instability had a high vibration level with low frequency. Spurious movements of the hip produced vibration with a low level and low frequency whereas a safe click had a low level of vibration and a higher frequency. Several infants went on to require treatment. When the records were examined retrospectively it was clear that the unstable hips were signalled at birth by low frequency, high amplitude vibration emissions. The study included a group of normal, clinically silent, hips, which also produced some vibration during testing, though on analysis these were entirely different vibrations. Using vibration arthrometry it was possible to predict or classify vibration detected from new hips

with unknown pathology. The result of testing this classification system suggested a sensitivity of 75%, a specificity of 99%, a positive predictive value of 86% and a negative predictive value of 99% ($p < 0{\cdot}005$). The technique of vibration arthrometry was proposed not only to facilitate hip screening, but also to assist with careful monitoring of clicky hips. The results of the trial permitted the Belfast hip screener to be updated, giving a preliminary diagnosis of hip disorders at the time of testing.

The analogue system of recording vibrations in developmental dislocation of the hip with its separate recording and later lab-based analysis stage, was a useful one for basic work and provided flexibility. However, it became clear that a more convenient and portable system would have advantages, particularly for less computer-literate users. One of the first attempts to reduce the system complexity involved a modified Apple microcomputer, which was programmed to record hip vibrations digitally during testing.[15, 16] The computer then acted both as a vibration datalogger and as an analyser. There were three phases of the software: capture, display and analysis. This system has come to be known as the Belfast hip screener and has allowed larger trials to be performed.

POPULATION STUDIES

A large-scale trial of vibration arthrometry for hip screening was carried out on a group of 3000 cases during December 1984 — December 1985 with final follow-up from 1988 to 1990. The aim was to evaluate the potential of vibration arthrometry in early detection of developmental dislocation of the hip on a representative group of neonates chosen at random from five maternity hospitals serving counties Antrim, Down and Tyrone. Since significant hardware development took place during the trial, not all vibrations were recorded in the same fashion. The initial 500 cases were recorded on analogue reel-to-reel tape.[17] The method proved valuable as it was possible to elicit vibration events from approximately one quarter of all the hips tested; vibrations were recorded from some normal hips, from all "clicky" hips, and from all unstable hips. The vibrations were measured and the differences between normal and "clicky" hips were statistically significant. The remainder have been categorised and detailed analysis is underway.

After further development of the computerised system, a clinical study of 300 neonates focused on the ability to detect hip vibration manually in a comparative study of vibration arthrometry with existing maternity screening practice. Over half (185) produced hip vibration during testing, including several cases who later received treatment. This random study of babies showed the value of vibration arthrometry in early detection of developmental dislocation of the hip, as very few hip vibrations (7%) were found by routine examination by a doctor. An experienced examiner, the research nurse, recorded 86% of the vibrations using the method of vibration arthrometry. It was concluded that objective screening by vibration arthrometry would detect a higher proportion of vibration events in neonates, during the early stages of developmental dislocation of the hip.

DISCUSSION

More widespread implementation of vibration arthrometry using this hip screener would warrant an economic appraisal. Twelve patients, who had recently received

hip replacement surgery as a result of late diagnosis of developmental dislocation were reviewed, and all their costs were identified, although no estimates were included for the pain and suffering endured by the patients.[18] We estimate that screening with the Belfast hip screener would be successful if it were able to raise the detection of developmental dislocation of the hip at birth from 50%, as at present, to 63%, with additional screening using ten teams of nurses examining every neonate in Northern Ireland.

Changes and improvements in treatment over the years, particularly antibiotic therapy, have reduced the hospital stay needed for corrective procedures. Therefore a study of the cost of treatment in a more recent cohort of cases of developmental dislocation of the hip was undertaken.[19] The potential cost-saving of screening, by examining the costs in 36 late cases born in 1980, was found to be £6,674 per case. This included all the costs of treatment up to 1991. While treatment costs have fallen, significant savings are still possible is cases are detected early because the cost of treatment in a nappy splint amounts to just £150. Of course, there are less quantifiable costs for the individuals diagnosed late; principally the lifetime pain and suffering resulting from failure to diagnose, but also loss of earnings.

The use of vibration arthrometry in practice depends on the method of discrimination, the ability to distinguish normal from abnormal. Decision analysis has been used to provide a discriminant method based on prior studies and this has been incorporated into the computer programme.[20] Furthermore the technique

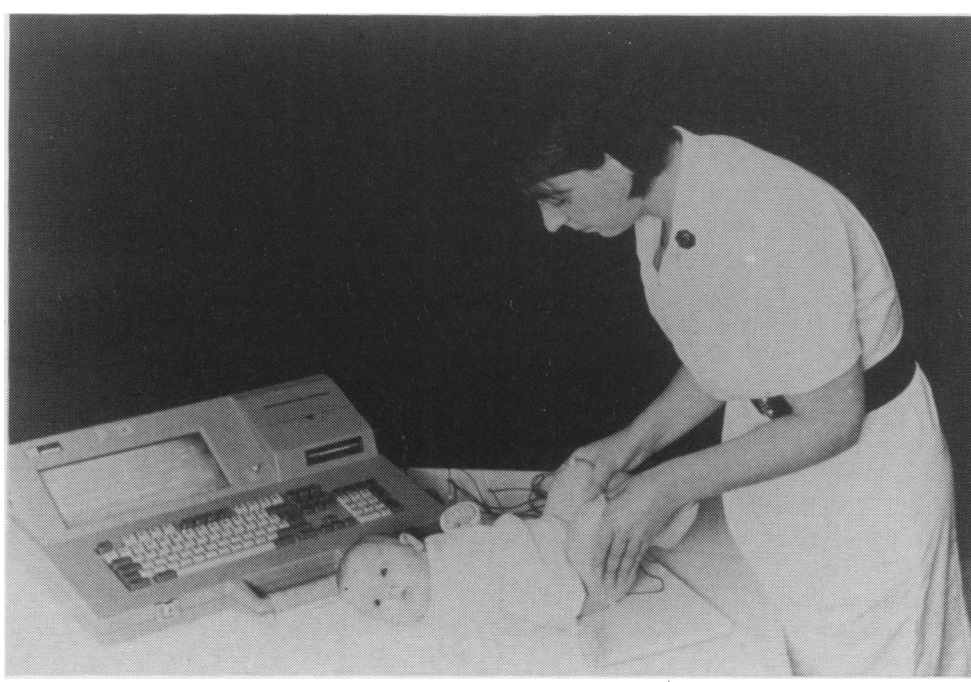

Fig 3. Vibration arthrometry is used in early detection of dislocated and dislocatable hips by recording and analysing vibrations produced during testing of the hip. The nurse is seen operating the Belfast hip screener.

depends on careful, reproducible expert manipulation of the neonatal hip, and current work has introduced additional sensors to measure applied force, angles, and displacement of the hip during testing. In this way the execution of the hip test can be monitored and standardised. Increased reproducibility amongst our population of responsible examiners will follow.

In order that more extensive clinical trials may be performed, the Belfast hip screener was redesigned (Fig 3) to meet British Standards (BS5724) and this was possible only with commercial support from the local electronics industry (Systems Solutions Ltd., 75 Belfast Road, Carrickfergus, N. Ireland). Eventually the benefits of this form of screening may be made widely available, and a marketing strategy devised in an attempt to achieve an early diagnosis of neonatal hip dislocation beyond the confines of Musgrave Park Hospital. Developmental dislocation of the hip is one of the biggest problems in paediatric orthopaedics. Without doubt, vibration arthrometry is not the complete solution, but there is evidence that important new information has become available using the technique. This has gained international recognition, and economic analysis has further shown that it may be implemented at little or no cost to the national health service.

REFERENCES

1. Bennett JT, MacEwen GD. Congenital dislocation of the hip. Recent advances and current problems. *Clin Orthop* 1989; **247**: 15-21.
2. Burke SW, Macey TI, Roberts JM, Johnston III C. Congenital dislocation of the hip in the American Black. *Clin Orthop* 1985; **192**: 120-3.
3. Crossan JF, Wynne-Davies R. Research for genetic and environmental factors in orthopaedic diseases. *Clin Orthop* 1986; **210**: 97-105.
4. Ilfeld FW, Westin GW, Makin M. Missed or developmental dislocation of the hip. *Clin Orthop* 1986; **203**: 276-81.
5. Klisic PJ. Congenital dislocation of the hip — a misleading term: brief report. *J Bone Joint Surg* 1989; **71B**: 136.
6. Morrissy RT, Cowie GH. Congenital dislocation of the hip. *Clin Orthop* 1987; **222**: 79-84.
7. Catford JC, Bennet GC, Wilkinson JA. Congenital hip dislocation: an increasing and still uncontrolled disability? *Br Med J* 1982; **285**: 1527-30.
8. le Damany P. La luxation congénitale de la hanche. Paris: Félix Alcan, 1912.
9. Ortolani M. Un segno poco noto e sua importanza per la diagnosi precoce di prelussazione congenita dell'anca. *Pediatria* 1937; **45**: 129-36.
10. Barlow TG. Early diagnosis and treatment of congenital dislocation of the hip. *J Bone Joint Surg* 1962; **44B**: 292-301.
11. Cowie GH, Mollan RAB, Kernohan WG, Bogues BA. Vibration emission in detecting congenital dislocation of the hip. *Orthop Rev* 1984; **13**: 30-5.
12. Cowie GH, Bogues BA, Kernohan WG, Mollan RAB. A new aid in the diagnosis of congenital dislocation of the hip. *J Bone Joint Surg* 1983; **65B**: 656.
13. Kernohan WG, Cowie GH, Patterson CC, Mollan RAB. Discriminating between innocent clicks and clunks due to dislocation of the neonatal hip. In: Societe Internationale de Recherche Orthopedique et de Traumatologie, Munich, 1987.
14. Kernohan WG, Cowie GH, Mollan RAB. Vibration arthrometry in congenital dislocation of the hip. *Clin Orthop* 1991; **272**: 167-74.

15. Shaw SN, Kernohan WG, Bogues BA, Mollan RAB. An Apple-based screening aid for congenital dislocation of the hip. *Proc Med Microcomput Appl.* Liverpool: University Press, 1985: 23-4.

16. Shaw SN, Kernohan WG, Mollan RAB. The development of a screening aid for congenital dislocation of the hip. In: Technology in health care. Byford GH (ed). Biological Engineering Society, London, 1985: 107-8.

17. Kernohan WG, Trainor BP, Nugent GEM, Walker PE, Timoney M, Mollan RAB. Low frequency vibration emitted from unstable hip in human neonate. *Clin Orthop* (In press).

18. Kernohan WG, Trainor BP, Mollan RAB, Normand CEM. Cost-benefit appraisal of screening for congenital dislocation of the hip. *J Management in Med* 1990; **4**: 230-5.

19. Kernohan WG, Trainor BP, Mollan RAB, Normand CEM. Cost of treatment of congenital dislocation of the hip. *Int J Health Plan Man* 1991; **6**: 229-33.

20. Kernohan WG, Patterson CC, Mollan RAB. Discriminant analysis applied to orthopaedics. In: *Applications of Statistics in Medicine,* Institute of Mathematics and its Applications, Cardiff 1988.