PROPrioception After RUPTURE OF THE
Anterior Cruciate Ligament

AN OBJECTIVE INDICATION OF THE NEED FOR SURGERY?

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Failure of conservative treatment is the usual indication for the reconstruction of a knee with deficiency of the anterior cruciate ligament (ACL) and this depends on subjective judgement. The ability of muscles to protect the subluxing joint by reflex contraction could provide an objective measurement.

We have studied 30 patients with unilateral ACL deficiency by measuring the latency of reflex hamstring contraction. We found that the mean latency in the injured leg was nearly twice that in the unaffected limb (99 ms and 53 ms respectively).

There was a significant correlation between the differential latency and the frequency of 'giving way' indicating that functional instability may be due, in part, to loss of proprioception. Measures of proprioception, including reflex hamstring latency, may be useful in providing an objective assessment of the efficacy of conservative treatment and the need for surgery.

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Deficiency of the anterior cruciate ligament (ACL) is a common cause of disability in young active patients. Mechanical instability allows forward subluxation of the tibia on the femur and impairs knee function. Primary repair or reconstruction of the ligament is not often performed; it is more usual to use conservative methods of treatment, in the form of physiotherapy, before considering an operation. The indication for surgery is often the failure of conservative management to restore the desired level of function, but this level is often assessed only by the patient's own evaluation. There are no reliable, objective assessments which can help in the decision for or against surgery. This 'trial and error' philosophy is unsatisfactory from both medical and resource management aspects.

Some recent research has focused on the proprioceptive rather than on the biomechanical role of the ACL (Solomonow et al 1987; Pope, Cole and Brand 1990; Johansson, Sjölander and Sojka 1991). There is no accepted definition of proprioception, but we have considered it as consisting of three components: 1) static awareness of joint position; 2) kinaesthetic awareness (the detection of movement and acceleration); and 3) closed-loop efferent activity which is required for the reflex response and the regulation of muscle stiffness.

There have been reports on the afferent aspects of proprioception (joint position sense and kinaesthesia) in patients with ACL deficiency (Barrack, Skinner and Buckley 1989; Barrett, Cobb and Bentley 1991; Corrigan, Cashman and Brady 1992) but we could find no work on the efferent aspect, that is, on the co-ordination of muscle activity and regulation of muscle stiffness for joint protection. Barrett (1991) found a significant correlation between function and joint position sense in ACL-deficient patients.

Our hypothesis was that an objective measure of the protective ability of the hamstrings, in terms of reflex contraction latency, will provide an indirect measure of the proprioceptive ability of the joint. This may well be a more appropriate measure of proprioception than the

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afferent joint position sense, since one aim of proprioceptive activity is to provide protection for the joint. This measurement could give an objective indicator of the efficacy of conservative management for chronic deficiency of the ACL, and this could be useful for the crucial decision as to the need for surgical reconstruction.

We postulated that complete rupture of the ACL results in impairment of a reflex protective mechanism, probably because of the loss of proprioceptive receptors in the ligament. We designed and constructed equipment to measure the latency of reflex protective contraction of the hamstrings, using the same subject's normal contralateral knee as the control. We examined the hamstrings because of their known role in protecting the ACL in the flexed knee (Walla et al 1985).

PATIENTS AND METHODS

We studied 30 patients, 27 male and 3 female, all with arthroscopically diagnosed deficiency of the ACL. Ethical approval was obtained from the Central Oxford Research Ethics Committee (Number 1957:1989). The patients were recruited from the day-surgery unit at the Nuffield Orthopaedic Centre, Oxford and all had sustained their injury less than 18 months before arthroscopy. The mean time since injury was 10.9 months (SD 4.1) and their mean age was 24.8 years (SD 5.9). No patient had received any rehabilitation which included proprioceptive or dynamic stability exercises. Patients were included in the study if they met the following criteria: 1) arthroscopically complete rupture of the ACL with no severe or complex meniscal damage; 2) age 16 to 50 years; and 3) a history of joint instability.

Patients were excluded for any of the following reasons:
1) grade III collateral ligament damage;
2) any symptoms in the contralateral knee;
3) any hip, ankle or foot problems;
4) previous intense rehabilitation or surgery for ACL deficiency;
5) history of any neurological abnormality; or
6) persistent pain and effusion at the time of measurement.

A standard set of routine static exercises was recommended to each patient before they attended for measurement at three weeks after their arthroscopy. Informed consent was obtained at this time.

Assessment. We assessed subjective knee function using the validated Lysholm and Gillquist (1982) functional scoring scale. Passive sagittal laxity was measured using a KT1000 arthrometer (Daniel 1991). Reflex hamstring reaction latency was measured by an experimental apparatus constructed for the study, the Vicon Interfaced Knee Displacement Equipment (VIKDE: Oxford Metrics Ltd, Bo Hey Road, Oxford. Fig. 1). This recorded the reflex hamstring contraction latency (RHCL) for each knee, using data from two sources sampled during the application of a posteroanterior shear force. These were surface EMG electrodes placed over the hamstring muscles, to give a record of the time of first contraction of the muscle, and a microphonic accelerometer attached to the anterior aspect of the tibial plateau, which gave the timing of the first displacement of the tibia.

Reflex activity of the hamstrings in response to the applied force could be clearly identified on the EMG trace, and a graphic display from a computer terminal enabled the latency to be computed as the time interval in milliseconds between the first recorded displacement.

![Diagram](image)

Fig. 1

Diagram to show the Vicon Interfaced Knee Displacement Equipment (VIKDE) for measuring reflex hamstring contraction latency (RHCL).

| Table I. Hamstring contraction latency, laxity and functional results in 20 control subjects |
|-----------------|------|------------------|
| Latency (ms)    | 43.2 | 15.9             |
| Latency differential (ms) | 4.2  | 2.5              |
| Laxity differential (mm)   | 0.48 | 0.76             |
| Lysholm score       | 100  |                  |

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<th>Table II. Hamstring contraction latency, laxity and functional results in 30 ACL-deficient patients</th>
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<td>ACL-deficiency (ms)</td>
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* significant at p < 0.0005
of the tibia and the first reflex reaction of the hamstrings. Before measurements were made on patients the apparatus was assessed for test-retest and intraoperator reliability. The correlation coefficients for these were 0.87 and 0.82 respectively, and it was found that changes in percentage weight-bearing and in auditory cueing affected reliability. These two variables were therefore controlled.

Both limbs were measured six times in each patient, and the mean values used for analysis. The difference in reflex contraction latency between limbs in each subject was then calculated.

**Statistical analysis.** We used the paired Student’s t-test for the statistical analysis between limbs in the ACL-deficient subjects, calculating 95% confidence limits and using a significance level of 0.05. A non-parametric Spearman test was used to identify correlations between latency, functional score and instability score. Graphs were drawn using the raw data with added regression lines.

**RESULTS**

We measured 20 normal subjects for validation purposes. The mean RHCL was 43.2 ms, and the mean interlimb differential 4.2 ms (95% CI 3.0 to 5.4; Table I). There was no significant difference in RHCL between limbs in the normal subjects.

Of the 30 patients with ACL deficiency, 29 showed an increased RHCL on the injured side: the hamstrings did not react as quickly to the displacement force. Mean RHCL for all 30 was 52.7 ms (95% CI 45.6 to 59.9) for the non-injured limb, and 98.8 ms (95% CI 87.1 to 110.5) for the ACL-deficient limb. The mean latency differential was 46.4 ms (95% CI 35.5 to 57.3; Table II). This difference was highly significant (p < 0.0005).

The mean Lysholm score for the ACL-deficient patients was 65 (95% CI 58 to 72). A score of 65 to 83 is 'fair' and below 65, 'poor' in terms of function (Fridén et al 1991). We found no correlation between passive AP laxity and functional score; there was some correlation between RHCL differential and the functional score in ACL-deficient subjects but this did not reach statistical significance.

There was a significant positive correlation (r = 0.62, p < 0.05) between the RHCL differential and the level of reported instability, derived from the functional score as the frequency of 'giving-way' episodes (Fig. 2). There was no significant correlation between anteroposterior sagittal laxity measured by the KT1000 arthrometer and the frequency of 'giving way' (r = 0.26, NS; Fig. 3).

**DISCUSSION**

The human anterior cruciate ligament is reported to provide 85% of the static resistance to excessive anterior shift of the tibia on the femur (Bessette and Hunter 1990). It is reasonable to assume that rupture of the ACL will lead to functional disability, but both research and clinical evidence have shown that this is not always true. The 'rule of thirds' of Noyes et al (1983a,b) is still considered to be one of the best indications of the distribution of disability in a population with ACL disruption. There is need to explain the differences in functional outcome in patients who have very similar pathologies.

The ligaments of the human body have long been considered as passive structures, and only recently, with the identification of specific intraligamentous sensory organs (Schultz et al 1984; Haus and Halata 1990; Zimny and Wink 1991), has their sensory role been discussed. It is likely that the neurophysiological proprioceptive
functions of ligaments are as important as their biomechanical role in maintaining joint stability (Johansson et al 1991).

Our study has shown that the reflex response to a controlled passive movement is significantly slower in a recently injured ACL-deficient knee than in the contralateral knee, or a normal control knee. The reflex response of muscles depends upon afferent signals from joint receptors, and also the level of preresponse muscle stiffness. The slowing of reflex muscle activity could therefore be due to the loss of proprioceptive input from the cruciate ligament, or from other proprioceptive receptors within the joint (Corrigan et al 1992).

There is some evidence that the dynamic stability of the knee can be improved by proprioceptively-biased rehabilitation (Ihara and Nakayama 1986), and it has been shown that patients with long-standing ACL deficiency develop a faster contraction of the hamstrings during walking on the damaged side, even without a formal rehabilitation programme (Branch, Hunter and Donath 1989; Kalund et al 1990; Sinkjaer and Arendt-Nielsen 1991). This ‘auto-conditioning’ of protective musculature may be one of the reasons why some patients (Noyes ‘first third’) achieve better function than others: they may have developed a compensatory proprioceptive mechanism which enhances their dynamic stability. Our patients were almost certainly not in this subgroup: they all had current problems with knee stability.

It is therefore suggested that, as well as muscle strength, proprioceptive loss should be assessed before deciding on surgery. Proprioceptive testing also allows an evaluation of the success of conservative management, including ‘auto-conditioning’ of muscle reflexes. The importance of the proprioceptive factor in rehabilitation is not yet fully appreciated or applied during conservative treatment (Beard and Fergusson 1992).

Patients with a large deficit in proprioception, as measured by hamstring contraction latency, may still have the capacity to improve with specialised physiotherapy, but those with no deficit in proprioception and adequate muscle strength have little to gain from further conservative treatment. In this way the measurement of hamstring contraction latency can add objective data to the subjective assessment of the need for surgery.

We have started a randomised clinical trial on the effect of special rehabilitation methods on proprioceptive loss (Ihara and Nakayama 1986). If improvement can be achieved, this will strengthen the case for such physiotherapy before the decision for operation on an ACL-deficient knee.

Conclusions
1) Reflex hamstring contraction latency is significantly greater in ACL-deficient knees than in either the contralateral non-injured knee or in control subjects.
2) The functional instability of the knee is directly related to the increase in reflex hamstring contraction latency.
3) The relative increase in reflex hamstring contraction latency is a measure of proprioception and can be used to provide objective data for the management of patients with chronic ACL deficiency.

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