The intra-operative radius joystick test to diagnose complete disruption of the interosseous membrane

Disruption of the interosseous membrane is easily missed in patients with Essex-Lopresti syndrome. None of the imaging techniques available for diagnosing disruption of the interosseous membrane are completely dependable.

We undertook an investigation to identify whether a simple intra-operative test could be used to diagnose disruption of the interosseous membrane during surgery for fracture of the radial head and to see if the test was reproducible.

We studied 20 cadaveric forearms after excision of the radial head, ten with and ten without disruption of the interosseous membrane. On each forearm, we performed the radius joystick test: moderate lateral traction was applied to the radial neck with the forearm in maximal pronation, to look for lateral displacement of the proximal radius indicating that the interosseous membrane had been disrupted. Each of six surgeons (three junior and three senior) performed the test on two consecutive days.

Intra-observer agreement was 77% (95% confidence interval (CI) 67 to 85) and interobserver agreement was 97% (95% CI 92 to 100). Sensitivity was 100% (95% CI 97 to 100), specificity 88% (95% CI 81 to 93), positive predictive value 90% (95% CI 83 to 94), and negative predictive value 100%.

This cadaveric study suggests that the radius joystick test may be useful for detecting disruption of the interosseous membrane in patients undergoing open surgery for fracture of the radial head and is reproducible. A confirmatory study \textit{in vivo} is now required.

The Essex-Lopresti syndrome combines a fracture of the radial head with disruption of the interosseous membrane.\textsuperscript{1-3} It is due to high-energy trauma with a longitudinally applied force producing a fracture that is usually displaced, requiring surgery, either reduction and internal fixation or replacement of the radial head.\textsuperscript{4,6}

If the disruption of the interosseous membrane is missed initially, many operations may be undertaken and they may fail to prevent severe functional impairment.\textsuperscript{7,9} Disruption of the interosseous membrane results in complex instability of the forearm in both the longitudinal and the transverse directions.\textsuperscript{1-3}

Methods suggested for assessing the integrity of the interosseous membrane include stress radiography,\textsuperscript{10} ultrasonography,\textsuperscript{11-14} and MRI.\textsuperscript{15-17} However, each of these has limitations. Plain radiographs may fail to provide the early diagnosis as the interosseous membrane is radiolucent.\textsuperscript{5,8} MRI is expensive and may be difficult to obtain on an emergency basis before surgery, and the results of ultrasonography depend heavily on the experience of the sonographer. Therefore the early diagnosis of disruption of the interosseous membrane disruption can be difficult to establish.

In the course of investigations using cadavers, we noticed that lateral traction applied to the radial neck induced no displacement when the interosseous membrane was intact and the forearm was placed in maximal pronation. We hypothesised that disruption of the interosseous membrane would result in lateral displacement of the proximal radius upon lateral traction with the forearm in maximal pronation.

We investigated whether the manoeuvre described above, which we have named the radius joystick test, when performed per-operatively would accurately reflect disruption of the interosseous membrane in patients with the Essex-Lopresti syndrome. We conducted a cadaveric study to investigate this, and also to assess whether the manoeuvre was reproducible.

Materials and Methods

A description of the radius joystick test is shown in Figure 1. Once the proximal radius is exposed through a posterolateral approach, a
clamp is placed on the radial neck. The forearm is placed in maximal pronation and the arm is held firmly to immobilise the humerus. The clamp is then pulled laterally, using moderate force. The test is positive if the proximal radius moves laterally, pivoting around its distal end in a manner resembling a joystick pivoting on its base. The test is negative if the radius remains immobile.

The study design and specimen preparation are shown in Figure 2. We used 20 normal fresh-frozen cadaver arms comprising the elbow, forearm and wrist. A physical examination and plain radiographs were performed to ensure that there were no deformities, scars, or restriction of pronation and supination, and that there had been no previous fracture or dislocation. The mean age of the donors at death was 71 years (65 to 83). The specimens were thawed 24 hours before the experiment.

All specimens were prepared by the same surgeon (MS). In each specimen, the radial head and neck were exposed through a posterolateral approach passing between the extensor carpi ulnaris and anconeus muscles and dividing the annular ligament vertically.18 The radial head was excised to simulate a severely comminuted and therefore irreducible radial head fracture requiring excision prior to introducing a radial head prosthesis. The incision was
extended to Lister’s tubercle of the distal radius, and an extensile posterior approach to the radius was performed.\textsuperscript{19} The interosseous membrane was exposed without detaching the dorsal forearm muscles from the radius and ulna.

The 20 forearms were divided at random into two groups of equal size. In ten specimens, the interosseous membrane, oblique cord, and quadrate ligament were completely severed (S group), whereas in the other ten specimens these structures were left intact (I group).

The joystick test was performed after severing the annular ligament of the radial head then again after exposing the entire interosseous membrane, in order to be certain that preparation of the specimens was not contributing to a positive joystick test. In all 20 specimens, these tests were consistently negative, indicating that the specimen preparation procedure did not cause false-positive results. Additionally, in order to determine whether partial section of the interosseous membrane was sufficient to give a positive joystick...
test in the S group, we performed the test after dividing only the proximal half of the interosseous membrane. This test was negative in all ten specimens in the S group. After performing the test and re-opening the forearm, we estimated the size of the tear in the membrane to determine whether there was any increase induced by the test.

For each specimen, once the preparation procedure was complete, the fascia and skin were meticulously sutured. The part of the incision corresponding to the radial head approach was left open to allow access to the radial neck. The S and I group specimens could not be distinguished visually.

The joystick test was then performed on each specimen by six surgeons with different levels of expertise in traumatology (three residents and three senior surgeons (GC, IK, VW)). None of them had performed this test before. They had received an oral description of the test by one of the authors (MS), as given above. Each of the six testers performed two series of joystick tests on each of the 20 specimens (20 × 2 = 40 tests for each tester) at an interval of one day. Therefore, 240 (40 × 6) tests were performed. On each of the two days, the specimens were tested in random order. This order was the same for all six testers. For each test on each specimen, the tester was asked to state whether the test was positive or negative.

Each tester was blinded to the status of the interosseous membrane, to the findings of the other testers, and to the number of specimens in the S and I groups. Between the first and the second day, the specimens were kept in a room with an ambient temperature of 20°C.

Radial nerve assessment. Once all the tests had been performed, the motor branch of the radial nerve was carefully dissected to look for evidence of section, stretching, or compression.

Data analysis. The result of each joystick test was considered a true positive (TP) when the test was positive in an S group specimen, a true negative (TN) when the test was negative in an I group specimen, a false positive (FP) when the test was positive in an I group specimen, and a false negative (FN) when the test was negative in an S group specimen. We used the results of the 240 tests to compute overall sensitivity (Se) and specificity (Sp) and the positive predictive value (PPV) and negative predictive value (NPV). The following formulas were used: Se = TP/(TP+FN); Sp = TN/(TN+FP); PPV = TP/(TP+FP); and NPV = TN/(TN+FN).

Sensibility, specificity, predictive positive value and predictive negative value of the radius joystick test are displayed with 95% confidence intervals (CI).

The proportions of agreement between both series (intraobserver agreement) and between surgeons (interobserver agreement) were calculated using Conger’s exact kappa.20 The 95% bootstrap confidence intervals were computed (1000 bootstrap replicates). Bootstrapping is a method that allows estimating a quantity based on the construction of numerous samples obtained by random sampling from the original dataset.21

Results

The results obtained on the first day are reported in Table I and those obtained on the second day in Table II. Intraobserver agreement was 77% (95% CI 67 to 85) and interobserver agreement was 97% (95% CI 92 to 100). Sensitivity was 100% (95% CI 97 to 100), specificity 88% (95% CI

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81 to 93), PPV 90% (95% CI 83 to 94), and NPV 100% (95% CI 97 to 100), respectively.

No evidence of damage to the motor branch of the radial nerve was found in any specimen on dissection performed after the tests.

During preparation of the specimens, when only half the interosseous membrane had been divided, performance of the test was not found to produce any noticeable increase in the size of the tear.

Discussion
These results suggest that the radius joystick test may be used for the intra-operative diagnosis of interosseous membrane disruption and would be highly reproducible. We found no evidence that it caused injury to the motor branch of the radial nerve.

The interosseous membrane serves as a longitudinal stabiliser of the forearm that prevents the proximal migration of the radius due to the pull of several muscles such as the biceps brachialii.2,3,22-24 At the wrist, proximal migration of the radius in patients with disruption of the interosseous membrane leads to a positive ulnar variance with impingement of the ulna on the carpal bones. If disruption of the interosseous membrane is overlooked it can result in a marked increase in the radiocapitellar load, leading to pain in the elbow after radial head arthroplasty or failed internal fixation of the radial head.25-28 If the disruption is recognised during initial surgical procedures such as temporary pinning of the distal radioulnar joint, radial head replacement (rather than more tenuous internal fixation), ligamentoplasty of the interosseous membrane29-33 can be performed to prevent proximal migration of the radius.

Our study has several limitations. First, the radius joystick test is subjective. Our aim was to describe an intra-operative test that was easy to perform and required no specific devices. For this reason, we did not give a precise definition of the intensity of the lateral traction or of the range of passive displacement, which would require the use of a dynamometer. Such precision is not necessary given the clear difference between a positive and a negative test, as shown by the high sensitivity, specificity, PPV, and NPV values and by the high inter- and intra-observer agreement in our study. On the first day, the random allocation procedure assigned the first three specimens to the I group and the first tested specimen with complete interosseous membrane was therefore the fourth specimen. Once the testers had experienced the first positive radius joystick test in this specimen they made no further mistakes. Thus, no false positive or false negative results occurred after the fourth specimen tested on the first day. The radius joystick test can be compared to the Lachman test34 used to diagnose rupture of the anterior cruciate ligament of the knee: this test is highly subjective and dependent on physician experience but is also very reliable.35,36 The second limitation is that we conducted our study on cadaveric specimens. In clinical practice, the high-energy trauma required to induce disruption of the interosseous membrane can cause severe soft-tissue swelling, which may limit passive mobility of the radius and therefore make a positive joystick test more difficult to detect.

We have performed this test during initial surgery in seven patients with a fracture of the radial head who gave their consent, including two patients with Essex-Lopresti syndrome diagnosed based on standard radiographs,
ultrasonography, and MRI and five patients with an intact interosseous membrane. The test was positive in the two patients with Essex-Lopresti syndrome and negative in the other five. We accept that absence of macroscopic damage to the motor branch of the radial nerve is not sufficient to confirm that the nerve has not been injured by the test, as stretching of the nerve can produce loss of function with no gross abnormalities. However, our clinical cases support the safety of the test, but further clinical observation is required before a definitive conclusion can be drawn. The third limitation is the theoretical risk of injury to the motor branch of the radial nerve due to placement of the clamp on the radial neck and to the lateral traction manoeuvre. However, dissection of this branch after testing revealed no macroscopic lesions. Additionally, none of the seven patients undergoing surgery upon whom the test was performed had a post-operative radial nerve palsy. The fourth limitation is the concern that lateral traction on the radius might transform a partial disruption of the membrane into a complete tear, but this was not found in any of our specimens when inspected after an initial partial division of the membrane. This finding suggests that performing the test with only moderate strength, as recommended, is unlikely to worsen a pre-existing partial tear.

Finally, this test can only be performed during open surgery. However, a high-energy injury is required to produce disruption of the interosseous membrane. As a result, the fracture of the radial head in Essex-Lopresti syndrome is often type II, III, or IV in the Mason classification scheme, necessitating open surgery.

The results of this cadaveric study suggest that the radius joystick test may be effective in diagnosing disruption of the interosseous membrane and the presence of Essex-Lopresti syndrome in patients with a displaced radial head fracture requiring exposure of the proximal radius. Moreover, this test seems to be very reproducible. A clinical study is now required.

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References