DIRECT LATERAL APPROACH FOR A PRIMARY THR

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Introduction

Multiple approaches to total hip arthroplasty have been described in the literature: Posterolateral, trans-trochanteric, direct lateral and Watson Jone's, recently mini-incision and minimally invasive hip approaches. Of all the approaches, the posterolateral [Moore's] and the direct lateral approaches are commonly used.

The posterior approach is considered to be easy to perform and easy to train residents, however, increased rates of dislocation have been reported. The direct lateral approach diminishes risk of hip dislocation and the risk of injury to the sciatic nerve. However, there is an increased risk of limp.

Dislocation of a hip prosthesis is a clinically important complication after THA, in terms of morbidity implications and costs. To minimize, risk of dislocation, the capsule and short external rotators in the posterolateral approach is sutured to the trochanter[24] and dislocation rate of 5-8% has been brought down to 1-3%. However, post-operative dislocation is still a problem in a posterolateral approach, more so when performed for fractured neck of femur[33], patients with neurologic problem like Parkinsonism It is well reported that the incidence of dislocation is much lower in the lateral approach compared to other approaches [13,24,29]. More recently, Masonis [18]analyzed 260 clinical studies including 4 prospective studies of which only 14 studies involving 13,203 Primary THR met the inclusion criteria. The combined dislocation rate was 1.27% for the transtrochanteric approach, 3.23% for the posterior approach 3.95% without posterior repair and 2.03% with posterior repair, 2.18% for the antero-lateral approach, and 0.55% for the direct lateral approach.. It has been suggested[15] that the available information is insufficient to make a firm conclusion on the optimum choice of surgical approach, a large prospective trial is required to prove usefulness of lateral approach.

The use of smaller surgical incisions has become popularized for total hip arthroplasty (THR) because of the potential benefits of shorter recovery and improved cosmetic appearance. Using incisions typically less than 10 cm in length, surgeons can achieve adequate visualization of the surgical site while minimizing trauma to deep soft tissues [17,32]. Small incision surgery is associated with a learning curve and requires specialized instruments for favorable outcomes. However, an increased incidence of serious complications has been reported [1]. These procedures should be reserved for selective specialized centers A comparative study by Woolson[37], 50 mini posterior incision and 85 standard posterolateral incision, suggested that there was no evidence that the mini-incision technique resulted in less bleeding or less trauma to the soft tissues of the hip, factors that would have produced a quicker recovery and a shorter hospital stay, than did the standard technique.

A modified lateral approach of Hardinge, which allows adequate access for orientation of the implant, has been described. Although this approach is more difficult than a posterior approach, and there is a learning curve, once mastered it definitely reduces the incidence of dislocation. In the Author's opinion, this approach should be used routinely for total hip arthroplasty for fractured neck of femur where the incidence of dislocation is unacceptably high using the posterior approach.

Evolution of Direct lateral approach

McFarland first described a direct lateral approach to the hip joint and Osborne [19](1954) based on the basic anatomical principle that the gluteus medius and vastus lateralis muscles act in functional continuity via their fascial connection over the greater trochanter. He detached the whole of the gluteus medius together with the vastus lateralis from the posterior border of the greater trochanter and swung them forward like a bucket handle. Similar approach is reported by Learmonth [16],. Hardinge [10](1982) popularized this approach by reflecting the anterior half of the gluteus medius and vastus lateralis. The Conjoint tendon [gluteus medius and vastus lateralis] gluteus minimus and capsule are lifted as a single flap. The conjoint flap is stitched with continuous stitch using a nonabsorbable material at the end of the procedure. McLaughlan [20](1984) elevated bone slices of trochanter anteriorly and posteriorly and these slices are taken anterior and posterior of Gluteus-vastus tendon. Dall [5](1986) modified his approach by taking an anterior sliver of the trochanter with conjoint flap [Liverpool approach]. He used cables to fix the trochanteric piece. Mullikan [23] (1998) modified further by taking less than one third anterior gluteus medius and vastus lateralis.

Pai [28] (2002) further modified this approach. This modification was different from the original Hardinge approach in following ways:

1) By splitting gluteus medius in its anterior 1/3rd , a large portion of the posterior two-third of the gluteus medius remains undisturbed at its point of insertion on the greater trochanter.

2) The superior extension of the abductor split is only 3-4 cm, maintaining a safe distance from the inferior branch of superior gluteal nerve.

3) The conjoint tendon [gluteus medius-vastus lateralis] and Gluteus minimus are lifted as one flap after are well separated from the capsule.

4) A "T" shaped incision is made on the anterior capsule with the vertical limb of the T along the intertrochanteric line and the horizontal limb across the anterior surface of the capsule to the acetabular rim. The capsule is retained and retracted.

5) With the posterior capsule intact and the anterior capsule repaired [the horizontal limb of the capsular incision] at the conclusion of surgery. This modification gives added soft tissue protection against dislocation.

6) On closure of the surgical wound, the gluteus-vastus flap is repaired to the bone with 2 ethibond to prevent avulsion of the flap from the bone.

7) Finally the patient is placed in the lateral decubitus position (cf. supine in Hardinge approach) which would allow direct visualization of the relevant anatomy. This also makes the job of the assistant easy.

  One potential drawback associated with this lateral approach is the risk of postoperative gluteal insufficiency. In theory, the superior gluteal nerve is at risk in this approach and can result in a positive Trendelenburg test. Jacobs [14] suggested that splitting of the gluteus medius proximally should be limited within five centimetres from the tip of the trochanter. Following their clinical and EMG studies Hardy[11] confirmed that the hip abductor function is not affected in the Hardinge approach. Baker [2] suggested that the gluteal limp is secondary to avulsion of the anterior conjoint tendon flap. Svensson [31] studied the

postoperative integrity of the conjoint aponeurosis of the gluteus medius and vastus lateralis in 97 consecutive THR performed via Hardinge approach. Two metal markers were placed in the aponeurosis, one on each side of the suture line. Trendelenburg gait was significantly increased only in the group of patients with a separation greater than 2.5 cm. He concluded that the gluteal insufficiency was due to postoperative elongation of the flap.

Author's Approach

Discouraged by an unacceptably high dislocation rate using the posterior approach, author turned to a direct lateral approach for total hip arthroplasty in 1991. After a period on the learning curve, incorporating some modifications, a standardized modified approach as described here has been used prospectively in 40 patients for total hip replacement for fracture neck of femur. No dislocation has occurred in these cases.

SURGICAL TECHNIQUE OF MODIFIED DIRECT LATERAL APPROACH Pre-operative : Templating is important. I use it to assess the cup size; joint centre to minimize limb length discrepancy and to determine whether high offset stem is required. All patients received 1 G Cephazole at induction, all were catherised pre-operatively. Surgery is usually carried out under Epidural anaesthesia with sedation or general anaesthesia.

Fig 1

Position: The patient is placed in the full lateral position on the operating table. One posterior post is placed just above the natal cleft and one against symphysis pubis. The contralateral leg is kept flexed and taped to the table as shown **[Fig 1]**

Skin Incision: A straight lateral skin incision is made midway between the anterior and posterior border of the greater trochanter centering on the tip of the trochanter measuring about 10-16 cm depending on the weight of the patient

Deep dissection: The fat and fascia lata are incised in line with the skin incision. Proximally fibers of gluteus maximus are split and retracted with a Charnley's self- retaining retractor. In the proximal part of the fascia lata, gluteus maximus insertion to the fascia lata is encountered which is split in line with the fascia lata **[Fig 2]**.

The trochanteric bursa is incised to demonstrate the anterior and posterior borders of the gluteus medius and the vastus lateralis. **[Fig 3]**

Fig 2

Fig 3

Elevation of the conjoint tendon: Blunt dissection is used to split the anterior third of the gluteus medius. Usually a layer of fat is visible deep to gluteus medius. This split is in the direction of the muscle fibres, which makes anterior 45 degrees' angulation to the skin incision **(Fig 4)**. The split is not extended more than 3 cm cephalad to the insertion of the trochanter to protect the inferior branch of the superior gluteal nerve.

Fig 4

Fig 5

Next, distal blunt dissection is carried out through the anterior part of the vastus lateralis passing down to the bone for about 4 cm. These fibres are divided and superficially and then separated with a self retaining retractor. Using a diathermy [on coagulation], the deeper fibres of vastus lateralis are split. The transverse branch of the lateral circumflex artery in the vastus lateralis is usually encountered and can be easily cauterized. **(Fig 5)**
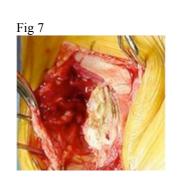

The now split portion of gluteus medius is connected to that of vastus lateralis over the greater trochanter at the junction of anterior third with posterior 2/3rd as shown in the **(Fig 6)** using electrocautery. With sharp dissection, elevate a flap consisting of the anterior part of the gluteus medius muscle with its underlying gluteus minimus and the anterior part of the vastus lateralis muscle.

Fig 6

Capsular incision: There is surgical plane between the glutei and capsule marked by areolar tissue, and dissection is carried out in this plane to the acetabular rim. The flap is retracted with a medially placed Hohmann's retractor [deep to anterior wall of the acetabulum]. Two blunt Hohmann's retractor placed extra-capsular above and below the neck of the femur. The patient's leg is externally rotated to visualize the full length of the capsule with its overlying ilio-femoral ligament. **(Fig 7).**

Fig 7

A "T" shaped incision is made on the anterior capsule with the vertical limb of the T along the intertrochanteric line and the horizontal limb across the anterior surface of the capsule to the acetabular rim **(Fig 8)**.

Fig 8

Dislocation of the joint: At this stage, the head of the femur is dislocated by flexion, adduction and external rotation. The leg is brought over into sterile pouch to perform a femoral neck osteotomy **(Fig 9)**. In osteoporotic bone, care should be taken during this manoeuvre and no force should be used to dislocate the hip. In difficult circumstances, a corkscrew is used to deliver the head or neck is osteotomised and the head is removed with the cork screw.

Fig 9

Fig 10

Acetabular exposure: The capsule is retained and is retracted using a self retaining retractor with one limb over the anterior capsule and other over the trochanter **(Fig 10)**.

Very rarely, Steinman pins, one placed at 11 O' clock and the other at 2 O' clock position on the outer aspect of the limbus are required. Rarely the approach may not be adequate and an additional capsulotomy is needed. This is performed at the 5 O' clock position, taking extreme care not to damage the sciatic nerve.

For acetabular preparation, one Hohmann's retractor is placed anteriorly and other in the acetabular notch beneath the transverse acetabular ligament. Rarely is a posterior rim retractor required.

The limbus is excised throughout the circumference of the acetabulum. The transverse acetabular

ligament is divided and excised. The acetabulum is prepared in the usual fashion using reamers to achieve concentric reaming.

For femoral preparation, the leg is held perpendicular to the floor. Care has to be taken while preparing the femoral shaft as it is not uncommon to damage the posterior fibres of the gluteus medius with the rasp. This can be avoided by retracting this muscle with a blunt Hohmann's retractor.

It is not necessary to excessively antevert or retrovert the acetabular or femoral components through this approach. In fact, it is generally acceptable to recreate the desired normal anatomy; that is,

Fig 13

approximately 15 degrees of acetabular anteversion and 5 –10 degrees of femoral anteversion. When proper soft tissue tension is achieved, stability of the joint can be demonstrated on flexion, adduction and internal rotation.

Closure: Careful attention to the detail of closure of the muscular layers is important to the success of this approach. A 1 Vicryl is used to repair the horizontal limb of the capsule **(Fig 13)**. The vertical limb of the capsule is not repaired. The conjoint tendon flap (gluteus medius and minimus, vastus lateralis) is repaired to the greater trochanter with bone stitches using 2 Ethibond **(Fig 14)**. The split gluteus and vastus are approximated with light 1 Vicryl stitches. The fascia lata, subcutaneous tissues and skin are closed in the usual fashion.

Fig 14

Postoperative rehabilitation following total hip arthroplasty has been carried out as follows: A pillow is placed between the patient's legs until they are awake in the recovery room. An AP radiograph is done in recovery ward to make sure joint is well contained All patients received 3 doses of IV antibiotics. Drains were removed after 24 hours. All patients received 20-40 units of Clexane [LMWH] for five days followed by low dose and Aspirin for 6 weeks. Ambulation with assistance is begun the next day. For the first 6 weeks, patients begin with crutch walking, progressing to full weight bearing as tolerated

.

DISCUSSION

THR is one of the most successful and rewarding operations ever developed. This surgery has undergone considerable evolution during the past 40 years; not only have a large number of prosthesis designs been developed but a large number of surgical techniques and approaches have been described. Good results can be achieved in the majority of cases irrespective of the type of approach following a primary THR. Despite these advances in total hip arthroplasty, dislocation remains a frequent complication and been reported to be 1-5% for primary osteoarthritis. This incidence can increase up to 18% for total hip replacement used for fractured neck of femur [33]. Dislocation can occur even after good orientation of the components and proper tissue tension. Pai[29] in a study of 35 consecutive displaced fractured necks of femur in the mobile independent elderly patient, performed by a single surgeon using a modified lateral approach. At two years, the overall early medical complication rate was 43%. There were no dislocations. Eighty percent had a good clinical outcome.

Poor prosthetic alignment is still a common cause for dislocation irrespective of type of approach [25]**]**. It has been reported that the movement in the replaced hip for a fractured neck of femur is greater than that for osteoarthritis and this may be a factor for increased incidence of dislocation [9]. Confusion, mental competence and balance problems may also contribute to the higher incidence of dislocation.

Posterolateral approach is simple and easy to train residents. Despite the modification of Moore's approach with fixation of the capsule and short rotators to trochanter, there is still a risk of dislocations, even in the hands of an experienced surgeon [18,36]. Taking these factors into consideration, it is important to adapt to an approach which gives consistently better results. There are prospective reports on direct lateral approaches and its modification, which give consistently a stable hip [13,18,23,29]. My modified approach has been used prospectively in 70 patients [unpublished data] with fractured neck of femur and early results are encouraging. It has to be noted that stability is well noted intraoperatively. This exposure was blamed for post-operative gluteal limp. It has been also noted that the gluteal limp has been overrated following approach [21,22].

In this modified approach, it is possible to damage the inferior branch of superior gluteal nerve. There are many studies[4,6,7,8,18] showing the strength of the abductors of the operated side is same as that on the non-operated side and functionally, the direct lateral approach is a safe alternative to other approaches..

There area many studies comparing direct lateral with other approaches:
Horwitz[12]: The direct lateral approach Vs Trochanteric osteotomy
The strength of the hip abductors, adductors, extensors, and flexors were measured at least 2 years following surgery. The strength of these muscle groups recovered to the same level as those on the non-operated side, and there was no significant difference between the two groups of patients. Functionally, the direct lateral approach is a safe alternative to trochanteric osteotomy.

Pai [27]: The direct lateral Vs Trochanteric and Liverpool approach The effects of lateral approaches to THR on Trendlenburg test and abductor strength were compared. In 264 patients with primary osteoarthritis, the Hardinge approach was used in 82 patients, the transtrochanteric approach in 94 and the Liverpool approach in 88. There is no difference in abductor efficiency and irrespective approach, abductor weakness was noted in 15%.

Downing[6]: The Direct lateral Vs Posterior approach Prospectively study of 100 patients undergoing THR via a lateral or posterior approach: Isometric abductor strength was measured with the kinetic communicator device and the Trendelenburg test was recorded preoperatively and at 3 and 12 months postoperatively. Hip abductor strength and the Trendelenburg test improved postoperatively in both groups and there was no difference in hip abductor strength recovery at 3 and 12 months between the lateral approach and the posterior approach. Similarly there was no difference in the Trendelenburg test between the two groups 3 and 12 months following hip replacement and the abductor weakness was noted in 15%.

Mesanis[18]: Posterior Vs Trochanteric Vs Lateral Vs Anterolateral Analyzed 14 studies involving 13,203 primary THR met the inclusion criteria based on variables previously shown to affect stability. The combined dislocation rate for these studies was 1.27% for the transtrochanteric approach, 3.23% for the posterior approach (3.95% without posterior repair and 2.03% with posterior repair), 2.18% for the anterolateral approach, and 0.55% for the direct lateral approach. Eight studies involving 2455 primary total hip arthroplasties evaluated postoperative limp. The incidence of postoperative limp was 4% to 20% for patients who had the lateral approach and 0% to 16% for patients who had the posterior approach.

There is always reluctance among surgeons to change the surgical approach which they are used to. But for those used to the posterior approach, adapting to the direct approach should not be a problem as both approaches are carried out in the lateral position.

The modified direct lateral as described in this study offers predictable and easy access to the hip joint and provides excellent exposure of both acetabular and proximal femoral regions. Dislocation is very rare, and postoperative limp is not a major problem. In this modified approach, the posterior capsule intact and the anterior capsule repaired, provides a soft tissue envelope around the joint. This may give additional stability against dislocation.

Complications
Nerve injury is a rare complication of total hip replacement which may be related to the exposure used for the operation. The posterior approach is traditionally associated with injury to the sciatic nerve. Weale[35] compared the incidence of nerve injury after primary total hip replacement (THR) using either a posterior or a direct lateral approach. The obturator, femoral, posterior tibial and common peroneal nerves were assessed clinically and electrophysiologically (EMG) and measurement of the velocity of nerve conduction before operation and at four weeks after. All

patients were free from symptoms of nerve injury after operation but five lesions were identified in four patients by the electrophysiological studies; the obturator nerve was involved in two, the femoral in one, the common peroneal in one. It is clear that clinically it is not relevant.

Picado [30] reported on 40 patients who had THR using the direct lateral approach to determine any correlation between superior gluteal nerve damage and abductor function. The Trendelenburg test was positive in 20 patients (50%) preoperatively and in 10 patients (25%) 1 year postoperatively. Seventeen patients (42.5%) had damage to the superior gluteal nerve visible on the first EMG evaluation performed 4 weeks postoperatively; three (7.5%) of these patients showed changes when revaluated 6 months postoperatively; only one of the three patients had a positive Trendelenburg test 1 year postoperatively. Nine of the 37 patients with normal electromyography results had positive Trendelenburg tests. They suggested that the damage tends to improve spontaneously and does not seem to cause clinically apparent abductor insufficiency.

Surgical approach may be a risk factor for the development of Heterotopic ossificans [HO] after THR. The lateral approaches, such as the McFarland, Liverpool, and Hardinge, there is increase possibility of HO compared with the transtrochanteric approach.. The Liverpool approach, which involves taking a sliver of trochanteric bone with the gluteal flap, is the lateral approach associated with the highest incidence of HO. The posterior approach for THA is associated with the lowest incidence of HO formation..[34,35] Except for the Liverpool approach, which produced HO five times more severe than that with the transtrochanteric or Hardinge approaches, the clinical implication of HO in these patients was not functionally significant.[25] However, severe form of HO [Brooker III,IV [3]] is very unusual in a modified lateral approach.

REFERENCES

1. Bal BS, Haltom D, Aleto T, Barrett M. Early complications of primary total hip replacement performed with a two-incision minimally invasive technique. Surgical technique .J Bone Joint Surg Am. 2006 Sep;88 Suppl 1 Pt 2:221-33

2. Baker AS, Bitounis VC.Abductor function after total hip replacement. An EMG and clinical review. J Bone Joint Surg Br. 1989 Jan;71(1):47-50.

3. Brooker AF, Bowerman JW, Robinson RA, Riley LM. Ectopic ossification following THR. 1973 J Bone Joint Surg 44(a):1629-35

4. Comstock C, Imrie S, Goodman SB.A clinical and radiographic study of the "safe area" using the direct lateral approach for total hip arthroplasty. J Arthroplasty 1994; 9(5):527-531

5. Dall D. Exposure of the hip by anterior osteotomy of the greater trochanter. J Bone Joint Surg 1986; 68B; 382-5

6.   Downing ND, Clark DI, Hutchinson JW, Colclough K, Howard PW. Hip abductor strength following total hip arthroplasty: a prospective comparison of the posterior and lateral approach in 100 patients. Acta Orthop Scand 2001; 72(3):215-220

7.   Frndak PA, Mallory TH, Lombardi AV Jr: Translateral surgical approach to the hip: the abductor split. Clin Orthop 1993; 295: 135-40

8.   Foster DE, Hunter JR. The direct lateral approach to the hip for arthroplasty. Advantages and complications..Orthopedics. 1987 Feb;10(2):274-80

9.   Gregory RJH, Gibson MJ, Moran CG. Dislocation after primary arthroplasty for subcapital fracture of the hip. J Bone Joint Surg 73(B):11-2

10.Hardinge K. The direct lateral approach to the hip. J Bone Joint Surg 1982; 64 B: 17-8

11.Hardy AE, Synek V: Hip abductor function after the Hardinge approach: brief report. J Bone Joint Surg (Br) 1988; 70(B):673-4

12.Horwitz BR, Rockowitz NL, Goll SR, Booth RE Jr, Balderston RA, Rothman RH, Cohn JC A prospective randomized comparison of two surgical approaches to total hip arthroplasty..Clin Orthop Relat Res. 1993 Jun;(291):154-63

13.Hungerford DS. Surgical approach in THA: the direct lateral approach is more practical and appealing. J Arthroplasty 2000;15(7):867-870

14. Jacobs LGH, buxton RA. The course of the superior gluteal nerve in the lateal approach to the hip. J Bone Joint Surg 1989, 71[1] 1239

15. Jolles BM, Bogoch ER Surgical approach for total hip arthroplasty: direct lateral or posterior?J Rheumatol. 2004 Sep;31(9):1790-6

16 Learmonth ID, Allen PE. The omega lateral approach to the hip. J Bone Joint Surg 1996;78(B):559-561

17. Malik A, Dorr LD. The science of minimally invasive total hip arthroplasty. Clin Orthop Relat Res. 2007 Oct;463:74-84

18. Masonis JL, Bourne RB. Surgical approach, abductor function, and total hip arthroplasty dislocation Clin Orthop Relat Res. 2002 Dec;(405):46-53.

19.McFarland B, Osborne G. Approach to the hip: a suggested improvement on Kocher's method. J Bone Joint Surg 1954;36 (B): 364-7

20. Mclauchan J The Stracathro Approach to the hip. J Bone Joint Surg 1984: 66B; 30-3

21. Minns RJ, Crawford RJ, Porter ML, Hardinge K. Muscle strength following total hip arthroplasty. J Arthroplasty 1993; 8(6):625-627

22. Mostardi RA. Comparison of functional outcome of the THA involving four surgical approaches. J Arthroplasty 1988, 3:279

23. Mulliken BD, Rorabeck CH, Bourne RB, Nayak N. A modified direct lateral approach in total hip arthroplasty. J Arthroplasty. 1998:13(7); 737-747

24. Osmani O, Malkani A. .Posterior capsular repair following total hip arthroplasty: a modified technique. Orthopedics. 2004 Jun;27(6):553-5.

25. Pai VS: Heterotopic ossification in total hip arthroplasty: The influence of the approach. *J Arthroplasty* 1994;9: 199–202

26. Pai VS. Significance of the Trendlenburg test in THR. J Arthroplasty 1996:11(2);174-9

27. Pai VS. LFA: A comparison between the transtrochanteric, Liverpool and Hardinge approaches. The MCh. Orthian Journal 1992:2,77-8

28. Pai VS. A Modified direct Lateral approach in Total Hip Arthroplasty J Orthop Surg 2002 Jun;10(1):35-9.

29. Pai VS,. Ardern D, Wilson N Fractured neck of femur in the mobile independent patient. J Orthop Surg. 2003 Dec;11(2):123-8

30. Picado CH, Garcia FL, Marques W. Damage to the superior gluteal nerve after direct lateral approach to the hip. Clin Orthop Relat Res. 2007 Feb;455:209-11.

31. Svenson O. Integrity of the gluteus medius after the transgluteal approach in THR. J Arthroplasty 1990; 5(1); 57-62

32. Swanson TV. Posterior single-incision approach to minimally invasive total hip arthroplasty. Int Orthop. 2007 Aug;31 Suppl 1:S1-5

33. Taine WH, Armour PC. Primary total hip replacement of displaced subcapital fractures of the femur. J Bone Joint Surg (Br) 1985: 67B: 214-7

34. Vicar AJ, Coleman CR. A comparison of the Anterolateral, transtrochanteric and posterior surgical approaches in THR. Clin Orthop 1975. 112; 201

35. Weale AE, Newman P, Ferguson IT, Bannister GC. J Bone Joint Surg Br 1996 Nov;78(6):899-902

36. Woo RYG, Morrey BF. Dislocation after total hip arthroplasty. J Bone Joint Surg (Am) 1982, 64: 1295-02

37. Woolson ST, Mow CS, Syquia JF, Lannin JV, Schurman DJ. Comparison of primary total hip replacements performed with a standard incision or a mini-incision.. J Bone Joint Surg Am. 2004 Jul;86-A(7):1353-8.