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Significance of the Trendelenburg Test in Total Hip Arthroplasty

Influence of Lateral Approaches

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Abstract: The effects of lateral approaches to total hip arthroplasty on abductor weakness and limp were studied 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 was no difference in functional level, range of movement, and limp among three lateral approaches. There was no increase in Trendelenburg gait after the Hardinge or Liverpool approach compared with the transtrochanteric approach. It is evident that the Trendelenburg test is a useful part of clinical examination if performed and interpreted correctly.
Key words: total hip arthroplasty, Hardinge approach, transtrochanteric approach, Liverpool approach, osteoarthritis, Trendelenburg test.

Total hip arthroplasty (THA) is one of the most rewarding operations ever developed. A vast number of patients have enjoyed the enormous benefits of an artificial hip joint. This surgery has undergone considerable evolution during the past 30 years.

Charnley emphasized importance of trochanter removal in THA.[1] Healing of the trochanter does not always occur, however; the rate of nonunion has been variously reported to be between 5 and 32%.[1-3] Alternatives to the transtrochanteric approach have been suggested.[3-8] The lateral approach to the hip was described by McFarland and Osborne.[7] Modifications of this approach, namely, the Liverpool[8] and Hardinge[6] approaches, are widely practiced in the United Kingdom. A major criticism of the direct lateral approach is that it violates the important abductor muscle mass and has potentially permanent sequelae, including postoperative limp and weakness.[9]

Following electromyographic studies, Hardy and Vladilmir confirmed that hip abductor function was not affected in the Hardinge approach.[10] Baker and Bitounis reported on an electromyographic and clinical review in patients undergoing hip arthroplasty by the Hardinge,[6] Dall,[3] and posterior approaches. They concluded that abductor weakness following the lateral approaches was due to avulsion of the anterior muscle flap from the trochanter rather than denervation of the gluteus.[11]

A similar conclusion was reported by Svensson, who studied the postoperative integrity of the conjoined aponeurosis of the gluteus medius and vastus lateralis in the Hardinge approach using metal markers.[12] Trendelenburg gait was significantly increased only in the group of patients with a separation greater than 2.5 cm.

This prospective study was undertaken to determine the effect of three commonly used lateral approaches (Hardinge, transtrochanteric, and Liverpool) on early function results of THA in a series of 264 cases of low-friction arthroplasty. Assessment

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was based on Charnley score, limp score, muscle strength, and the Trendelenburg test.

Materials and Methods

Between January 1987 and October 1989, 354 Charnley low-friction arthroplasty (Wrightington F. C. Hip, Howmedica, Rutherford, NJ) procedures were performed by three consultants at the Clatterbridge Hospital (Wirral, United Kingdom). Of the 354 operations, 264 were selected for this study: 82 Hardinge, 88 Liverpool, and 94 transtrochanteric. To maintain the groups' compatibility, secondary osteoarthritis, rheumatoid arthritis, previous hip operations, and infected total hips have been excluded. The average age of the 264 patients was 68.2 years. There were 159 women and 105 men.

Approaches

Transtrochanteric Approach. The trochanter is cut using a Gigli saw (Downs, Sheffield, United Kingdom) to create a biplane osteotomy. The trochanter is fixed using a single horizontal compression wire and double vertical wire.[13]

Hardinge Approach. The gluteus medius is reflected anteriorly in continuity with a portion of vastus lateralis in a bucket handle fashion. This is accomplished by sharp dissection close to the trochanter. The conjoint tendon with capsule is elevated as a single flap.[6]

Liverpool Approach. This approach is similar to the Hardinge approach. The only modification is that a sliver of trochanter is taken with the gluteal flap so as to allow better fixation of the flap to the greater trochanter during closure.[8]

Assessment

All the patients have been followed for at least 1 year, with a mean follow-up period of 2.2 years (range, 1–4 years). Each patient was assessed for numerical grading, gait status, power of abductor, Trendelenburg test, and use of walking aids.

Numerical Grading. The system of d'Aubigne and Postel grades pain, walking abilities, and passive range of motion for each hip on a scale of 6, with 6 representing normality and 1 the worst possible situation.[1]

Power of the Abductors. *Medical Research Council Grading.* Abductor power of the hip was tested with the patient lying on the side, attempting to abduct the leg against resistance. The recommended Medical Research Council grading is as follows:

Grade 0: No active contraction can be detected.
Grade I: A flicker of muscle contraction.
Grade II: Contraction produces movement with gravity eliminated.
Grade III: Contraction produces movement against gravity.
Grade IV: Strength is subnormal, but can produce movement against gravity and resistance.
Grade V: Normal.

Trendelenburg Test. A standard method was used.[14] The examiner stands behind the patient and observes the angle between the line joining the iliac crest and the ground.

The patient is asked to raise one leg (sound side) off the ground with the hip flexed at 30°. Once balanced, the patient is then asked to raise the nonstance side of the pelvis as high as possible. (If the patient is unstable, a supporting stick can be used in the hand only on the side of the weight-bearing hip or the examiner can support both shoulders.) If the patient leans too far over to the side of the weight-bearing hip, the examiner corrects this by gentle pressure on the shoulders to align the trunk over the stance side hip.

The response is classified as follows:

1. Normal: if the pelvis on the nonstance side can be elevated high up and is maintained for 30 seconds.
2. Elevation of the pelvis is present but not maximal.
3. Pelvis is elevated but not maintained for 30 seconds.
4. No elevation of the pelvis on the nonstance side.
5. Drooping of the pelvis.
6. Nonvalid response: presence of hip pain, uncooperative patient.

In this study, responses 1 and 2 were considered normal. The Trendelenburg test was positive when the response to the test was 3, 4, or 5.

Radiologic Assessment. Trochanteric union was assessed in the Liverpool and transtrochanteric approaches and classified as bony union in normal or migrated position, fibrous union, or complete detachment. The widest distance between the trochanteric fragment and the trochanteric bed was measured in the transtrochanteric approach.

Results

Overall, there were no significant differences between the Hardinge, Liverpool, and transtrochanteric groups with respect to pre- and postoper-

Table 1. Mean Improvement in Grading

	Approach		
	Transtrochanteric	Liverpool	Hardinge
Pain			
Preoperative	2.6	2.7	2.6
Postoperative	5.8	5.8	5.8
Mean difference	3.2	3.1	3.2
Walk			
Preoperative	2.9	2.7	2.8
Postoperative	5.5	5.6	5.7
Mean difference	2.6	2.9	2.9
Range of motion			
Preoperative	3.0	3.0	3.1
Postoperative	5.8	5.7	5.8
Mean difference	2.8	2.7	2.7

ative Charnley scores: pain, function, and range of motion (Table 1). Function scores before operation were 2.8 for the Hardinge group, 2.7 for the Liverpool group, and 2.9 for the osteotomy group. Postoperative scores were 5.7, 5.6, and 5.5 for the Hardinge, Liverpool, and transtrochanteric approaches, respectively. The limp score at 1 year after surgery was similarly represented by three groups, and none of the patients with limp had significant limb-length discrepancies.

Pain relief and range of motion in patients with positive Trendelenburg test results were comparable to those observed in negative tests (Table 2). Limp score was reduced, however, in the patients with positive Trendelenburg test results, as compared with the patients with negative results (4.7 vs 5.8).

Gait was analyzed during follow-up examinations. Two hundred three patients walked with a normal gait without the use of an assisted device. Of the remaining 61 patients, 29 had significant contralateral hip disease and required a cane for support and 14 used canes occasionally, such as during long-distance walking, for security and stability.

Table 2. Trendelenburg Test Results and Mean Improvement

	Positive Trendelenburg Test (44 patients)	Negative Trendelenburg Test (220 patients)
Pain		
Preoperative	2.8	2.7
Postoperative	5.4	5.8
Mean difference	2.6	3.1
Walk		
Preoperative	2.9	2.8
Postoperative	5.2	5.8
Mean difference	2.3	3.0
Range of motion		
Preoperative	2.9	3.1
Postoperative	5.8	5.8
Mean difference	2.9	2.7
Aids		
Preoperative	3.2	3.3
Postoperative	5.0	5.9
Mean difference	1.8	2.6
Limp		
Preoperative	3.5	3.4
Postoperative	4.7	5.8
Mean difference	1.2	2.4

Charnley scores: Pain: (1) while resting, (2) severe on walking, (3) tolerable, (4) after activities, (5) occasional, (6) none. Function of walking: (1) bedridden, (2) limited indoors, (3) limited distance with stick, (4) long distance with stick, (5) no stick but limp, (6) normal. Range of movement (sum of all ranges): (1) < 30°, (2) 30°–60°, (3) 60°–100°, (4) 100°–160°, (5) 160°–210°, (6) > 210°. Aids: (1) wheelchair always, (2) two crutches, (3) two canes, (4) one cane, (5) cane only for long distance, (6) none. Limp: (1) cannot walk, (2) few steps with gross limp, (3) walks with gross limp, (4) moderate limp, (5) slight limp, (6) normal.

Table 3. Abductor Power versus Approaches

Medical Research Council Grade	Approach		
	Transtrochanteric	Liverpool	Hardinge
I	0	0	0
II	1	1	1
III	3	6	5
IV	19	23	18
V	71	59	58

Table 4. Trendelenburg Test versus Approaches

Response	Approach		
	Transtrochanteric (n = 94)	Liverpool (n = 88)	Hardinge (n = 82)
Maximal elevation	52	45	52
Submaximal elevation	21	23	13
Positive delayed response	8	7	9
No elevation of pelvis	6	3	3
Drooping	4	2	2
Nonvalid response	3	8	3

Chi-square = 0.67 (2 *df*), $P = .71$. No statistical difference among the three approaches.

Abduction function was unaffected by the type of approach (Table 3). No significant differences were found between the surgical approaches when the efficiency of the hip abductor mechanism was assessed by the Trendelenburg test and by the patient's ability to abduct the hip actively (Table 4). The Trendelenburg test was positive (response 3, 4, or 5) in 18 (19%) patients in the transtrochanteric group, 12 (15%) in the Liverpool group, and 14 (18%) in the Hardinge group; however, drooping of the pelvis was seen in only 8 patients. Twenty-four patients had a delayed positive response; 11 of these 24 walked normally despite a positive test.

Table 5. Positive Trendelenburg Test Response versus Limp Score

Trendelenburg Test Response	Limp Score	No. of Patients (n = 44)
Delayed response (3)	6	11
(24 patients)	5	13
No drooping (4)	6	1
(12 patients)	5	9
	4	1
	3	1
Drooping (5)	5	3
(8 patients)	4	3
	3	2

Trendelenburg test response: (1, 2) normal, (3) delayed response, (4) no elevation, no drooping, (5) drooping of pelvis, (6) nonvalid. Limp score: (1) cannot walk, (2) walks few steps with gross limp, (3) walks with gross limp, (4) walks with moderate limp, (5) walks with slight limp, (6) normal.

Table 5 demonstrates limp scores in abnormal Trendelenburg test responses.

The radiologic assessment of trochanteric healing revealed a bony union in 82 patients (87%) in the transtrochanteric group and 74 (83%) in the Liverpool group, indicating that there is no difference in trochanteric healing. In five patients in the transtrochanteric group and three in the Liverpool group, complete detachment of the trochanter was obvious. In the transtrochanteric group, 8 of 10 hips with a trochanter displaced more than 1 cm had a positive Trendelenburg sign. The linear trend is significant ($P < .001$), suggesting that abductor power is influenced by the degree of displacement (Table 6).

Discussion

No one approach to the hip has gained universal acceptance for THA. Charnley advocated a complete trochanteric osteotomy,[1] but the question of trochanteric osteotomy in a primary THA remains controversial. The Hardinge approach and its modifications are popular in the United Kingdom. This approach avoids the complications attributed to standard trochanteric osteotomies while providing adequate exposure for the procedure. One potential drawback, however, is the risk of postoperative gluteal insufficiency.[15] In theory, the superior gluteal nerve is at risk in this approach.[16] If it is damaged, weakness of abduction of the hip and

Table 6. Trendelenburg Test Response versus Trochanteric Healing in the Transtrochanteric Approach

Trendelenburg Test Response	Amount of Trochanter Displacement (cm)				
	0	< 1	1–2	2–3	> 3
Normal	44	5	2	1	—
Submaximal elevation	16	5	—	—	—
Delayed positive	7	1	—	—	1
No elevation	1	2	1	—	2
Drooping	0	—	—	1	2
Nonvalid response	3	—	—	—	—
Total	71	13	3	2	5

Chi-square for linear trend = 22.82 (1 *df*). $P < .001$; that is, the greater the displacement, the more likelihood of a positive Trendelenburg test.

therefore a positive Trendelenburg test can result. It had been reported earlier that abductor weakness following the Hardinge approach was due to avulsion of the muscle flap from the greater trochanter rather than due to damage to the superior gluteal nerve.[11,12]

Ambulation following THA can be affected by pain, hip abductor strength, and range of motion.[17] In addition to clinical assessment, various investigations have been reported: gait analysis,[18] isometric measurements,[18–20] and electromyographic studies.[10] Although strength is related to function, isometric measurement should not be relied on as the sole predictor of function.[20] There is no single test that adequately evaluates all aspects of function.

The Trendelenburg test is valuable in that it allows for functional assessment in a confined space. At 1 year after surgery, there was no significant difference in the incidence of a positive Trendelenburg test among the three approaches. Although drooping of the pelvis was observed in only eight patients (3%) when the criteria of Hardcastle and Nade were applied,[14] a positive response was seen in 19% in the transtrochanteric group, 15% in the Liverpool group, and 18% in the Hardinge group. Frndk et al. reported a modified Hardinge approach to the hip in 65 hips, and none of the patients had a positive Trendelenburg test;[5] however, they noted normal gait in only 40 patients and difficulty in abduction against gravity in 6 patients. In contrast, in this study, all cases of gluteal weakness had a positive Trendelenburg test.

A delayed Trendelenburg test was positive in 24 patients in this study (Table 6). Half of them were walking without a limp. A positive delayed response, although important in the assessment, does not preclude a good to excellent result on the limp score; however, it must be noted that all patients with a positive Trendelenburg test had aching about the hip with endurance activities.

A positive Trendelenburg test, abnormal gait on fatigue, or a progressively severe limp that appears after surgery is a poor prognostic sign for durability of the implant.[18] Although Charnley scores improved vastly in all patients, the negative Trendelenburg test group fared better with respect to function than the positive test group.

Muscular dysfunction around the hip joint is usually secondary to a pathologic hip.[21] Pathologic changes that alter hip biomechanics can affect the capacity of muscles to generate force and moment about the hip.[22,23] In addition, arthritic hip pain can elicit an inappropriate Trendelenburg response.[14] Therefore, the Trendelenburg test is misleading in the preoperative assessment.

In the transtrochanteric group, 12 (13%) patients had nonunion, with 5 complete detachments of the trochanter. Displacement of trochanter greater than 1 cm is likely to cause abductor weakness.[9] This study confirms that the greater the displacement, the more likelihood there is of an unsatisfactory lurching gait and a positive Trendelenburg test ($P < .001$).

Conclusion

I agree with Horwitz et al.[19] that there is no difference in functional level, range of motion, and limp among the three lateral approaches. There is no increase in Trendelenburg gait after the Hardinge or Liverpool approach compared with the transtrochanteric approach.[4,21] It is evident that the Trendelenburg test is a useful part of clinical examination if performed and interpreted correctly.

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References

1. Charnley J: Low friction arthroplasty of the hip: theory and practice. Springer-Verlag, Berlin, 1979
2. Amstutz HC, Maki S: Complications of trochanteric osteotomy in total hip replacements. J Bone Joint Surg 60A:214, 1978

3. Dall D: Exposure of the hip by anterior osteotomy of the greater trochanter. J Bone Joint Surg 68B:382, 1986
4. Foster D, Hunter JR: The direct lateral approach to the hip for arthroplasty: advantages and complications. Orthopedics 10:274, 1987
5. Frndk PA, Mallory TH, Lombardi AV: Translateral surgical approach to the hip. Clin Orthop 295:135, 1993
6. Hardinge K: The direct lateral approach to the hip. J Bone Joint Surg 64B:17, 1982
7. McFarland B, Osborne G: Approach to the hip. J Bone Joint Surg 36B:364, 1954
8. Surendra K: Brief review of approaches for total hip arthroplasty and comparing Liverpool and Charnley approaches. MCh (Ortho) thesis, University of Liverpool, Liverpool, UK, 1979
9. Nutton RW, Checketts RG: The effects of trochanteric osteotomy on abductor power. J Bone Joint Surg 66B:180, 1984
10. Hardy AE, Vladilmir S: Hip abductor function after the Hardinge approach. J Bone Joint Surg 70B:673, 1988
11. Baker AS, Bitounis VC: Abductor function after total hip replacement. J Bone Joint Surg 71B:47, 1989
12. Svensson O: Integrity of the gluteus medius after the transgluteal approach in THR. J Arthroplasty 5:57, 1990
13. Wroblewski BM, Shelley P: Reattachment of the greater trochanter after hip replacement. J Bone Joint Surg 67B:736, 1985
14. Hardcastle P, Nade S: The significance of the Trendelenburg test. J Bone Joint Surg 67B:741, 1985
15. Obrant K, Ringsberg K, Sanzen L: Decreased abductor strength after Charnley hip replacement without trochanteric osteotomy. Acta Orthop Scand 52:345, 1981
16. Jacobs LGH, Buxton RA: The course of the superior gluteal nerve in the lateral approach to the hip. J Bone Joint Surg 71A:1239, 1989
17. Johnston RC, Fitzgerald RH, Harris WH et al: Clinical and radiographic evaluation of total hip replacement. J Bone Joint Surg 72A:161, 1990
18. Long WT, Dorr LD, Healy PT, Perry J: Functional recovery of noncemented total hip arthroplasty. Clin Orthop 288:73, 1993
19. Horwitz BR, Rockowitz NL, Goll SR et al: A prospective randomized comparison of two surgical approaches to total hip arthroplasty. Clin Orthop 291:154, 1993
20. Vaz MD, Kramer JF, Rorabeck CH, Bourne RB: Isometric hip abductor strength following total hip replacement and its relationship to functional assessments. J Orthop Sports Physical Ther 18:526, 1993
21. Shih C, Du Y, Lin Y, Wu C: Muscular recovery around the hip joint after total hip arthroplasty. Clin Orthop 302:115, 1994
22. Cahalan TD, Jonson ME, Liu S, Chao EYS: Quantitative measurements of hip strength in different age groups. Clin Orthop 246:136, 1989
23. Vasavada A, Delp SL, Maloney WJ et al: Compensating for changes in muscle length in total hip arthroplasty. Clin Orthop 302:121, 1994