Intrapelvic protrusion of the acetabulum was first recognized by Otto in 1824 on a desiccated specimen from the Natural History Museum of Breslau in Poland (Fig. 1). Otto originally described the abnormality as being an important consideration in obstetric delivery and ascribed his findings to “an abnormal gout.” To date, he has remained the only author to make this association. White reported the first case in the British literature in 1883. Protrusio acetabuli received scant attention until the turn of the 19th century. Since then, this condition has been the subject of much debate regarding diagnosis, etiology, and management. This inward protrusion of the acetabulum is commonly referred to as Otto pelvis, protrusio acetabuli, or arthrokatadysis (from ancient Greek: literally meaning subsidence of a joint). The term Otto-Chrobak pelvis was used for a number of years after Eppinger added the name of a Professor Chrobak as a birthday tribute. However, Chrobak’s name was dropped as he had no connection with the condition.

**Historical Considerations**

Otto described the macroscopic appearance of the acetabulum and head of femur as being “smooth and polished with a loss of the cartilage cover.” Eppinger, in 1903, reporting on four similar pelvic specimens, suggested that the deformity resulted from a disturbance of growth affecting the delayed ossification of the triradiate cartilage. The continued pressure from the femoral head was then sufficient to cause the protrusion.

Over the following 30 years, a number of authors published reports which suggested a variety of alternative pathologies. Kuliga (cited in Pomeranz) favored an “osteo-arthritis deformans,” while Hertzler; Pomeranz, and Lewin (cited in Pomeranz) described an “osteoarthritic protrusion of the acetabulum.” Infection was also identified as a possible cause, with tuberculosis, gonorrhea, and syphilis being the most commonly reported conditions responsible. Streptococcus, staphylococcus, and echinococcus were also identified in diseased hips.

In 1929, Doub found 50 cases of protrusio with a wide variance of opinion as to the exact etiology. He failed to identify any one etiological factor and suggested that the most likely explanation was that some general disease in early life causing softening of the bones led to the deformity, with osteoarthritis a later stage in the process.

Pomeranz, in 1932, identified 79 cases, accepted that it was incorrect to seek one common etiology, and described two main groups of patients. One group developed protrusio secondary to infection. In the second group, the protrusio was associated with generalized osteomalacia.

Schaap and Golding, in 1934, agreed with Pomeranz’s hypothesis and included a further group conforming with Eppinger’s opinion that, in some, a growth disturbance primarily initiated the deformity. Schaap also compared patients in this group, who were mostly females and in whom the condition tended to be bilateral,
with patients with developmental dysplasia of the hip.9

The suggestion of more than one etiology for the condition became widely accepted, with the exception of Rechtman11 who, in 1936, suggested that all cases of protrusio had an initially “too deep” acetabulum as a congenital deformity.

Overgaard,12 in 1935, first distinguished between primary and secondary protrusio. He subdivided the primary group into those with osteo-asthenic protrusion and those with osteo-arthritic protrusion. The secondary group showed evidence of a destructive inflammatory process in the joint.

Gilmour,13 in 1939, further simplified this classification so that the primary group contained only those patients in whom no other underlying pathology was demonstrable, while subjects in the secondary group developed protrusio as a result of any underlying pathology. This is the classification used today.

Etiology

Secondary Protrusio

The causes of secondary protrusio acetabuli are now well documented (Table 1). In most subjects with secondary protrusion, the progression of the deformity can be explained in terms of the underlying condition.

Where there is a destructive process, such as infection, the femoral head will migrate axially, close to the line of the joint reaction force as the bony substructure is weakened. Similarly, in inflammatory conditions, migration will occur due to increased bone turnover under load. The joint reaction force acts at 69° from the horizontal14 and migration of the femoral head in protrusio occurs just medial to this at 65°.15

Conditions which weaken the bone matrix, either locally, such as radiation induced osteonecrosis, or globally, such as Paget’s disease, will also allow the femoral head to migrate superomedially under normal loading conditions.

However, these simple explanations do not explain the progression of the condition in all the recognized causes of secondary protrusio. One example is the occurrence of the deformity in Marfan’s syndrome. Marfan’s syndrome is caused by a defect in the fibrillin 1 gene. This defect gives rise to cardiovascular, skeletal, ocular, pulmonary, integument, and dural abnormalities. The skeletal manifestations of Marfan’s syndrome are best explained by overgrowth of the long bones as opposed to a weakness in their structure. A lack of normal fibrillin in the periosteum might give less restriction to longitudinal growth, and subsequent overgrowth occurs due to this lack of negative feedback.16 To simply attribute the protrusio in these patients to a weakness in the acetabular floor is unfounded. It would be equally likely to result from the growth disturbance which gives rise to the other features. This hypothesis would support a possible developmental

Table 1 Etiology of Secondary Protrusio Acetabuli

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<tr>
<th>Category</th>
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<td>Infection</td>
<td>Gonococcus</td>
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<td>Idiopathic Chondrolysis</td>
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<td>Metabolic</td>
<td>Paget’s Disease</td>
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<td>Osteomalacia</td>
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<td>Hyperparathyroidism</td>
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<td>Genetic</td>
<td>Osteogenesis Imperflecta</td>
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<td>Acrodysostosis</td>
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<td>Marfan Syndrome</td>
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<td>Ehler-Danlos Syndrome</td>
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<td>Trisomy 18</td>
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<td>Stickler Syndrome</td>
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<td>Neurofibromatosis</td>
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<td>Sickle Cell Disease</td>
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<td>Trichorrhuphalangeal Syndrome</td>
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<td>Homocystinuria</td>
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<td>Primary Neoplasm (e.g., Hemangioma)</td>
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<td>Metastatic Disease</td>
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<td></td>
<td>Radiation Induced Osteonecrosis</td>
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<tr>
<td>Trauma</td>
<td>Acetabular Fracture</td>
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etiology in some protrusion patients.

**Primary Protrusio**

Primary protrusio acetabuli remains a diagnosis of exclusion, and as such many of the cases reported in the past may have in fact been secondary to undiagnosed conditions. In the search for an etiology responsible for the primary protrusio group, most investigators have referred to the mechanisms responsible for secondary protrusio. Thus, the possible etiologies have been considered under the following three headings:

1. An inflammatory or destructive condition of the hip joints;
2. A qualitative deficiency of acetabular bone; and
3. A developmental abnormality or growth disturbance.

**Clinical Features**

The condition presents in three main age groups: patients presenting in their teens, those presenting between 35 and 50 years, and those presenting between 51 and 85 years. This division was based on a graphical representation of the age at presentation in 59 patients. While there is a definite peak in the younger patients, division of the later onset patients into two distinct groups is less well-defined.

In younger patients, the diagnosis of protrusio is often overlooked, as it is unusual for any features of degenerative change to be present at this stage. The condition in this age group, although producing the associated signs and symptoms of protrusio, often lacks the striking radiographical appearance seen in later life. Below the age of 25, osteoarthritic stigmata are minimal. Above this age, the degree of osteoarthritic changes correlates positively with the age of the patient. The younger patients present when symptoms arise from the anatomical abnormality. The older patients, instead, present when degenerative change occurs secondary to this abnormality. This is in agreement with Gilmore’s belief that there was a primary phase in which the deformity existed in an uncomplicated state, but that it was more often discovered when osteoarthritic or other changes had set in. In the elderly patients studied by Hooper and Jones, protrusio was invariably accompanied by osteoarthritis, which in itself is a cause of secondary protrusio. By the time that the gross changes of osteoarthritis are manifest, it is impossible to distinguish those in whom the protrusio results from osteoarthritis from those in whom the protrusio pre-dated the degenerative changes.

There is a marked female to male preponderance. Scandalis and colleagues reported the incidence according to sex of 85% female (35 out of 41 patients). Gilmore found a similar ratio of 30 females to 7 males.

The condition is characteristically bilateral. In Overgaard’s review in 1935, 35 of 44 patients had bilateral protrusio. Of the nine patients reported as unilateral, six had an abnormally deepened contralateral acetabulum. Details of the contralateral hip of the remaining three were unavailable.

Rechtman first suggested a hereditary pattern in three of the five patients he described. This was suggested from history alone, with the probands reporting a similar functional disability in members of their immediate families. Rechtman was unable to access the other family members to confirm this radiographically. Since then, this familial link has been confirmed radiographically by a number of investigators and has also been demonstrated in identical twins. The suggested patterns of inheritance have been in accordance with an autosomal dominant gene with incomplete or complete penetrance.

There is also a racial influence on the condition with a greatly increased incidence in the Bantu women in Natal. Pelvic radiographs of pregnant Bantu, Indian, and European women referred for pelvimetry were compared. The incidence of primary protrusio acetabuli in these groups was 25.7% (58 out of 226), 5.7% (6 out of 105), and 2.9% (3 out of 105), respectively.

In 1939, Gilmore reported an abnormal “rhythm of adolescent development” in patients with protrusio. In a number of his patients, the signs and symptoms of the deformity had preceded menarche, and these girls showed accelerated epiphyseal growth and fusion prior to this. Friedenberg, in a report of two patients, commented that one of them experienced menarche at 9 years of age and that both had experienced early fusion of the epiphyses.

With the exception of two patients who had repeatedly elevated calcium levels in the series by Hooper and Wyn Jones, all the patients reported showed normal biochemical analysis. An abnormality may indeed exist, but it may be too subtle to be detected by routine screening methods.

Shore and associates described the histological appearance of biopsy specimens from juvenile patients as showing a significant but non-diagnostic inflammatory reaction. Specimens from arthroscopic examination showed degenerative changes with fibrocartilage replacement. Wroblewski and Hillman performed histological examination on specimens of the acetabular floor from patients with the features of idiopathic protrusio undergoing total hip arthroplasty. The marrow spaces were replaced with active vascular fibrous granulation tissue with disruption of the trabecular pattern in some areas.

Typically, patients with primary protrusio acetabuli present with increasing stiffness rather than pain. Often, stiffness has been noticed in adolescence. Histories from the various series include one young lady who noticed that she could not sit cross legged on the floor and another who found that she lacked hip flexibility.
while attempting gymnastics at school. Of those who present later with symptoms of secondary degenerative change, close questioning often reveals similar histories of preceding limitations of movement. Deepening of the acetabulum leads to painful limitation of abduction as the femoral neck impinges on the superior acetabular margin. The pain is presumed to arise from synovial structures in this region. Further progression leads to adductor spasm, and fixed flexion deformities develop. There is often hyperlordosis of the lumbar spine which compensates for the fixed flexion deformities at the hips. Untreated, the patient ultimately develops ankylosis of the affected hip.

**Radiological Features**

The term “Protrusio Acetabuli” simply refers to the protrusion of the acetabulum into the lesser pelvis, and this occurs to varying degrees. It is commonly reported as a chronic progressive deformity. Brailsford, following the progress of the deformity in young patients, concluded that the onset of the condition was in infancy and that the deformity followed a slowly progressive course. In the same year, however, Friedenberg suggested that, although the protrusion occurred at a young age, it did not always continue to increase. He provided evidence for this statement with one of his own patients as having no progression of deformity between radiographs taken at 31 years and 39 years. He also pointed out that Schaap and Golding had both followed up females of 45 and 40 years of age, respectively, for five years with no progression of acetabular protrusion. Hubbard, in 1969, describing his findings on 27 patients with protrusion, confirmed that not every case of protrusio was progressive. In his series, 20 hips in 15 patients progressed by an average of 6 mm in a mean of 8.4 years, 10 hips in six patients had no progression in a time ranging from 1 to 10 years, and 10 hips in six patients actually showed a decrease in protrusion.

The non-progressive cases of Friedenberg, Schaap, and Golding showed preservation of the articular cartilage in the presence of marked protrusio. Figure 2 demonstrates the typical radiographic appearance of the condition in a patient with minimally progressive deformity.

Sherlock, in 1995, suggested that primary protrusio acetabuli and acute idiopathic chondrolysis may have been the same condition. In the absence of Marfan’s syndrome, infection, trauma, or rheumatoid arthritis, a diagnosis of primary protrusio acetabuli was made if an adolescent presented with pain and stiffness of the hip and acetabular protrusion and loss of joint space were apparent on plain radiography. The same picture, but in the absence of protrusio, would beg the diagnosis of acute idiopathic chondrolysis. Of five adolescent females with the former clinical picture, three had been diagnosed as having primary protrusio acetabuli, and two as having acute idiopathic chondrolysis. The similarities in the clinical features and CT findings led Sherlock to believe that they were likely to be one condition. He proposed that those patients with pain as the predominant feature had tended to be labeled as acute idiopathic chondrolysis, whereas those with a more definite protrusio were labeled primary protrusio acetabuli. The association of protrusio with acute idiopathic chondrolysis has been commented on by other investigators.

Chondrolysis of the hip has been described secondary to slipped upper femoral epiphyses since 1930. In 1971, Jones first described idiopathic chondrolysis in the absence of any other pathology. This uncommon condition was initially reported as being more common in black, adolescent females. More recent literature has recorded its occurrence in Caucasian, Indian and Hispanic males and females. Bilateral cases are

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**Figure 2 A.** Radiograph showing the typical appearances of primary protrusio acetabuli in a 19-year-old Caucasian female. Note the marked protrusio and the preservation of the joint space. **B.** Radiograph of the same patient at 29 years of age demonstrating the non-progressive nature of the condition.
exceptional. The radiographic findings in acute idiopathic chondrolysis show a global loss of articular cartilage on the femoral head and acetabulum.

In the juvenile group of patients with primary protrusio acetabuli of Hooper and Wyn Jones, males and females were equally affected. In some, the symptoms progressed rapidly, becoming incapacitating. Therefore, in the younger age group, acute idiopathic chondrolysis and primary protrusio acetabuli may well be two distinct pathologies that are difficult to separate at the time of presentation. In acute idiopathic chondrolysis, the chondrolytic process causes global loss of articular cartilage and secondary protrusio develops. This group contains a more even male to female ratio and the process is often unilateral. In primary protrusio acetabuli, the protrusio develops with sparing of the articular cartilage. This group has the characteristic female preponderance and bilateral deformity. Other investigators have included acute idiopathic chondrolysis in their lists of causes of secondary protrusio acetabuli.

Several investigators have disagreed with Otto’s description of his original specimen as having “a normal size and shape in general.” Overgaard described a typical “clover leaf” appearance on radiographs and several other investigators found a widened intercristal distance on anteroposterior pelvic radiographs. Alexander also demonstrated that the ratio between the intertuberos distance and the intercristal measurement was lower in patients with primary protrusio acetabuli and higher in patients with developmental dysplasia of the hip. Little further work has been published in this area. This finding could be explained by forward tilting of the pelvis due to fixed flexion deformity at the time of radiography, but, to our knowledge, to date this effect has not been investigated.

Coxa vara and decreased femoral antversion have been linked with primary protrusio acetabuli. Hooper evaluated the femoral neck-shaft angle in their patients: all measurements were within the normal range, averaging between 123° and 127°. In a comprehensive review of femoral and acetabular anteverision, found that primary protrusio acetabuli was associated more with increased femoral and acetabular anteverision rather than retroversion, but he included too few patients to draw any definite conclusions. It would certainly seem unlikely that there is any marked relationship between primary protrusio acetabuli and either coxa vara or decreased femoral anteverision.

With these clinical and radiographical features, the etiology of primary protrusio acetabuli would most likely be developmental. A bilateral condition affecting only the acetabula, with preservation of the articular cartilage and normal inflammatory markers, is unlikely to have an inflammatory or destructive etiology. Likewise, the non-progressive nature of the acetabular deformity, the normal biochemical profile, and the lack of other sites affected would make a qualitative deficiency of bone unlikely. Currently, two hypotheses exist regarding a developmental etiology:

1. A disturbance of growth may lead to a delay in ossification of the triradiate cartilage. Subsequent stresses on the unfused epiphyses would produce the deformity.
2. The converse of this might be the case: abnormal acceleration of epiphyseal ossification in the pelvis replacing the triradiate cartilage with new, vascular and plastic bone that allows molding under weight bearing. Alexander showed that a degree of protrusio was normal in children. He described a “beaking” of the triradiate cartilage which is at a maximum at eight years of age and which subsequently remodels. He also suggested that accelerated epiphyseal closure may lead to preservation of this physiological protrusio that then failed to remodel.

Experiments on rabbits have shown, however, that premature surgical fusion of the triradiate cartilage leads to a thick medial acetabular wall with progression to subluxation of the hip. This finding has also been demonstrated in children following acetabular fractures. Premature closure suspected to be the result of septic arthritis of the hip has also been reported with subsequent subluxation. Surgical closure of the triradiate cartilage has also been described as an effective treatment in arresting the development of protrusio in skeletally immature Marfan’s patients. Steel recommends this procedure in children with Marfan’s who are between the ages of 8 and 10 years and who have documented progression of acetabular deepening. This evidence would imply that early epiphyseal closure leads to a shallow, dysplastic acetabulum rather than protrusio. Any link between late epiphyseal closure and abnormal acetabular development has yet to be documented.

Radiographic Diagnosis
The term “protrusio acetabuli” simply refers to the protrusion of the acetabulum into the lesser pelvis. This was first demonstrated radiographically by Schertlin in 1910. Gross examples of the condition are obvious on standard antero-posterior radiographs of the pelvis, with the outline of the acetabulum extending beyond the iliopectineal line. Sotelo-Garza and Charnley graded the deformity in these patients. The distance between the projection of the upper margin of the superior pubic ramus and the outline of the acetabulum protruding into the pelvis was estimated, giving three grades of protrusio.

Grade I (mild protrusio) measured 1 to 5 mm;
Grade II (moderate protrusio), 6 to 15 mm; and
Grade III (severe protrusio), more than 15 mm.
At earlier stages in the progression of the condition the diagnosis is not always so apparent. As a result, various radiographic criteria have been used to try to identify the most consistent method of diagnosis. Before these methods are described, it has to be stressed that in a condition such as protrusio, where the range of deformity extends along a continuum from near normal to grossly abnormal, any value chosen is necessarily arbitrary.

The three most widely used criteria are the center-edge angle of Wiberg, the distance between the medial wall of the acetabulum and Kohler’s ilioschial line, and the configuration of the teardrop.

The center-edge angle, originally described to diagnose developmental dysplasia of the hip, is shown in Figure 3A. An angle less than 20° was taken as diagnostic of developmental dysplasia of the hip, and an angle greater than 46° as diagnostic of protrusio. “Grey areas” probably lie between 20° and 25°, and 40° and 46°, with a normal range between 25° and 40°. Some investigators have supported the use of this angle, but others have found it unreliable in the diagnosis of primary protrusio acetabuli. Freidenburg and MacDonald found center-edge angles greater than 50° and as high as 90° in radiographs of obvious protrusion. Armbruster, in an anatomical study of the adult hip, found no correlation between the center-edge angle and either the teardrop configuration or the distance between the acetabular line and the ilioschial line. He also found a wide range of values, as high as 59°, in the normal population.

Sharp observed several limitations of the center-edge angle. The center point of a deformed femoral head is difficult to locate, and subluxation or simple loss of joint space of either hip leads to inaccurate measurements. These patients also develop superolateral osteophytes that make identification of the superolateral edge difficult.

The relationship of the acetabular line, representing the medial wall of the acetabulum, to Kohler’s ilioschial line, has also been used by several investigators. Alexander, as one of his diagnostic criteria, required the femoral head to reach Kohler’s line. He admitted that his criteria were too rigid and lead to under-diagnosis. Hubbard required the acetabular line to cross the ilioschial line as part of his diagnostic criteria. In a series by Armbruster and coworkers, however, in women the acetabular line crossed the ilioschial line by an average of 1 mm in the normal population, and in men 2 mm lateral to it. They recommended that a diagnosis of protrusio be made if the acetabular line crossed the ilioschial line by 3 mm in men and by 6 mm in women. In their hands, this measurement was reliable even with minor degrees of rotation, as they considered both these structures to be centrally placed. Goodman and colleagues, however, radiographed dried pelvic specimens while serially sectioning and reaming the specimens. They demonstrated that, while the teardrop was a consistent representation of the medial and lateral walls of the floor of the acetabulum just above the obturator foramen, the ilioschial line was a projection of a portion of the quadrilateral surface posterior to the acetabulum. Thus, the separation of the two lines would be sensitive to rotation of the pelvis at the time of radiography. They suggested that, as the teardrop was a consistent finding, a Cartesian coordinate system based on this structure should be used for diagnosis and charting progression. This suggestion has been further reinforced by Gates and associates, and is useful to chart progression of the condition.

The appearance of Kohler’s “teardrop” figure has long been commented on with regard to acetabular deepening. In 1935, Overgaard noted that inversion of the
“pear-figure” (teardrop) represented a deepening of the acetabulum. The various appearances of the teardrop are shown in Figure 4. The definitions shown are those employed by Armbuster and colleagues, Alexander, Hooper and Jones, and Hubbard all used the crossing of the teardrop as one of their diagnostic criteria for protrusio. However, Armbuster showed that this appearance is also very sensitive to pelvic rotation. Kohler himself demonstrated this variability on poorly centered films.

In the absence of a proven “standard” diagnostic criterion, it is impossible to separate normal hips from those with an abnormal protrusion. One must therefore be careful in what conclusions are drawn from comparisons between different proposed diagnostic measures. The evidence would suggest that patients with protrusio demonstrate high center-edge angles above the reported normal range. However, this measurement is unhelpful in diagnosis due to its lack of specificity. To overcome these inaccuracies the inter-teardrop line should be used as the baseline rather than the center-center line in this measurement. Both the appearance of the teardrop and the separation of the acetabular and ilioischial lines are helpful in diagnosis, provided that care is taken to ensure accurate centering of films. The only measurement method that would eliminate the effect of rotation would be to use Cartesian coordinates with the origin at the tip of the teardrop.

Several other indices of acetabular morphology have been described in the investigation of developmental dysplasia of the hip. These include the acetabular index or sourcil angle, the acetabular inclination angle, and the acetabular depth-to-width index. Murphy and co-workers assessed the usefulness of these variables as prognostic indicators in developmental dysplasia of the hip. The sourcil tends to be concave inferomedially in protrusio, giving a negative acetabular index. Apart from this observation, no work has been carried out using these measurements in a group of protrusio patients.

**Management**

The management options for primary protrusio acetabuli have been recently reviewed (Table 2). The most appropriate treatment is based on the age and skeletal maturity of the patient, the degree of protrusio, and the extent of degenerative changes in the joint.

In skeletally immature patients, surgical fusion of the triradiate cartilage has been proposed. Steel recommends this procedure in Marfan’s Syndrome following his results on a series of 22 patients, as the secondary protrusio that develops is progressive. At present, it is not possible to anticipate which cases of juvenile primary protrusio acetabuli will progress and which will follow a more indolent course. Therefore, the use of this procedure in primary protrusio acetabuli currently remains unclear.

In the time predating total hip arthroplasty, surgical management of the condition included resection arthroplasty, arthrodesis, and acetabuloplasty. Acetabuloplasty with resection of the anterior wall of the acetabulum was performed for the first time on a 55-year-old female with bilateral protrusio to remove the area of impingement that

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Table 2 Operative Procedures for Protrusio Acetabuli

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<td>Arthrodesis</td>
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<td>Total Hip Arthroplasty</td>
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<td>Acetabuloplasty</td>
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<td>Valgus Intertrochanteric Osteotomy</td>
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<td>Surgical Closure of Triradiate Cartilage</td>
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gave rise to her painful symptoms. The patient was able to return to work as a housekeeper four months later. At the time of publication the procedure had been used on 11 patients. Eight of these were performed for “malum coxae senilis,” two for old slipped capital femoral epiphysis, and the original procedure was performed for one patient with primary protrusio acetabuli. No long-term follow-up study has been published on this procedure, although a similar acetabuloplasty or “rimectomy” is still being performed in some centers (C. Wynn-Jones, personal communication).

The two most widely used operative procedures for primary protrusio acetabuli are valgus intertrochanteric osteotomy and total hip arthroplasty. Pauwels\(^{63}\) first described valgus intertrochanteric osteotomy for use in protrusio hips, and reasoned that the procedure led to more cranial resultant forces at the hip joint, thus reducing the pressure on the floor of the acetabulum. The other beneficial effect of the procedure is that it reduces the impingement at the superior acetabular margin. Since then, several investigators have reported excellent results in selected patients following valgus intertrochanteric osteotomy, with the best results in younger patients with minimal arthritic change in the hip joint.\(^{62}\) In a study with eight operated hips in six patients and a maximum follow up of 5 years, the results were good except for 1 patient, who was 49 years old at the time of operation and had moderate arthritic changes visible radiographically.\(^{63}\) McBride and associates\(^{61}\) reported on 19 hips operated on in 12 patients with an average follow up of 7.2 years. Good to excellent results were documented in 12 hips in patients aged between 21 and 33 years. Poor results were noted in five hips in the four patients aged 42 and over. McBride and associates concluded that this procedure should not be performed on patients over 40 years of age or in whom significant degenerative changes were evident on plain radiographs.\(^{7}\) Of the seven patients in the personal series of the authors of this article, three over 40 years of age were operated on and all of these achieved a good or excellent result at an average follow up of 5.3 years. None of these patients had significant degenerative changes evident in their preoperative radiographs.

In older patients or in patients with significant degenerative changes, the best operative procedure for primary protrusio acetabuli is total hip arthroplasty. Sotelo-Garza and Charnley\(^ {53}\) demonstrated no significant difference in outcome in total hip arthroplasty performed on 253 protrusio hips compared with those performed on non-protrusio hips. The importance of replicating the original anatomy of the hip joint has been stressed. Ranawat and coworkers\(^ {64}\) demonstrated cement-bone demarcation around the acetabular cup in all three zones, as described by DeLee and Charnley,\(^ {65}\) in 16 of 17 hips positioned 1 cm or more from the anatomical position. Failure of acetabular prostheses malpositioned to this degree has been further confirmed by Gates and colleagues\(^ {59}\) and Bayley and associates.\(^ {66}\) Crowninshield and coworkers\(^ {67}\) performed finite element analysis on various types of prosthesis when positioned anatomically or with medi- dial displacement. Higher medial stresses resulted from medial placement of the acetabular component. Lateral placement with metal backing of the component or the use of a protrusio cup lessened these medial stresses. Prosthetic reinforcement of the medial wall had little benefit other than that of containment of any cement used. The use of a morselized or fragmented bone graft is an effective means of lateralization of the cup.\(^ {15,68}\) As well as returning the hip joint to its anatomical position, the graft is incorporated into the medial wall improving bone stock in this region.\(^ {7}\) Ranawat and Zahn\(^ {69}\) reported on 27 arthroplasties performed for protrusio. When the degree of protrusio was less than 5 mm, they did not use bone graft. When the degree of protrusio was greater than 5 mm but the medial wall remained intact, autologous bone graft without artificial fixation devices was recommended. Finally, in patients with a grossly deficient medial wall, reconstruction with bone graft and additional fixation is required. Hirst and associates\(^ {70}\) reported their findings on 61 hips operated on in 51 patients and followed up for an average of 4 years and 3 months. In these patients, the degree of protrusio was determined by the grading used by Sotelo-Garza and Charnley\(^ {53}\) rather than a measurement defining migration from the anatomical position. All patients were operated on with the same technique. The medial wall was reinforced with wafers of autologous bone graft cut from the femoral head, sufficient to lateralize the cup. Cement was pressurized over this layer and into peripheral keyholes. A flanged cup was then pushed firmly into position. There was no relapse of protrusio in any of these cases.

**Conclusions**

Primary protrusio acetabuli remains a diagnosis of exclusion in patients with abnormal medialization of the acetabulum and in whom the secondary causes listed in Table 1 have been ruled out.

While the exact etiology remains obscure, primary protrusio acetabuli is a developmental condition with hereditary and racial influences. It is progressive in adolescence, prior to fusion of the triradiate cartilage, after which the deformity remains static until superimposed with secondary degenerative changes. It is most likely that delayed ossification rather than early fusion of the triradiate cartilage is responsible. Alternatively, the deformity may develop during an accelerated growth spurt. Further work is required to identify the exact developmental mechanism and any possible genetic etiological factors.

The current methods employed in radiographical diagnosis of protrusio acetabuli all use an arbitrary cut-
off point between normal and abnormal anatomy. When looking at a condition with a spectrum of deformity, this inevitably leads to over- or under-diagnosis, depending on the cut-off point chosen. Certainly, patients with protrusio acetabuli tend to have a center-edge angle greater than the reported normal upper limit of 46°; the teardrop configuration tends to be closed, crossed, or reversed; and the acetabular line tends to cross Kohler’s line by more than 3 mm in men and more than 6 mm in women. However, none of these measurements have the sensitivity or specificity to provide a reliable diagnostic system. Grading systems, such as those used by Sotelo-Garza and Charnley or Ranawat and Zahn are more useful as they allow categorization of patients.

The management of protrusio acetabuli depends on age and degree of degenerative change. In the young, skeletally immature patient with progressive secondary protrusio acetabuli, early surgical fusion of the triradiate cartilage with or without valgus intertrochanteric osteotomy is appropriate. As it is not possible to anticipate which patients with primary protrusio acetabuli in the younger age group will progress to a severe deformity, fusion of the triradiate cartilage cannot be recommended for primary protrusio acetabuli. Valgus intertrochanteric osteotomy is recommended in skeletally mature patients with no degenerative change under 40 years of age. Over 40 years, this procedure can still be carried out in patients with no degenerative changes in their hip joint and who are capable of undertaking the associated rehabilitation. In older patients, total hip arthroplasty with medial bone grafting and meticulous attention to returning the hip joint to its anatomical center is the procedure of choice.

References

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