Screening for Hip Instability in Newborn Infants and Treatment in the Original von Rosen Splint

Review of the first 50-years’ experience in Sweden

Göran Hansson
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In memory of three professors to whom I remain grateful for supporting me when choosing the medical profession or as my mentors during my training to become a paediatric orthopaedic surgeon.

3. Robert B. Salter (1924 - 2010) Toronto, Canada
Göran Hansson, MD, PhD, was born in 1942. He went to medical school in Gothenburg, Sweden and graduated in 1973. He obtained specialist licence in Orthopaedics in 1978 and presented his Thesis, “Neonatal Hip Instability, in Gothenburg, Sweden, between 1961 and 1970”, at the University of Gothenburg in 1980. He spent two years training in paediatric orthopaedics in North America, one year as Clinical Fellow with Professor Robert B Salter at The Hospital for Sick Children, Toronto and one year with Professor Norris Carroll at The Children’s Memorial Hospital, Chicago. In 1990 he was appointed as Associate Professor at Uppsala University. He has been a member of the board of The European Paediatric Orthopaedic Society (EPOS) and is a member of The International Paediatric Orthopaedic Think Tank (IPOTT). He has published more than 50 papers on topics including hip disorders in children, children’s fractures and congenital clubfoot.
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FOREWORD

This beautifully illustrated book provides persuasive evidence for the efficacy of systematic early screening by physical examination of the hip in newborn infants. The facts that 90 per cent of neonatal hip instability in Sweden is diagnosed prior to discharge from maternity wards, is treated effectively in a simple brace and is complicated by avascular necrosis in less than one per cent of those treated are truly impressive and set an exemplary international standard for the detection and treatment of Developmental Dislocation of the Hip (DDH). Dr. Hansson emphasizes that screening must be universal, conducted by experienced examiners and delays beyond the first several days of life lead to poorer results because success of treatment may no longer be guaranteed and the rate of avascular necrosis will increase. This book also includes a comprehensive history of the diagnosis and treatment of DDH over the past century.

The reliance in Sweden on clinical examination alone for the initial diagnosis seems to be at variance with other European countries that rely on ultrasonography for detection, often delayed for a week or two to avoid over-diagnosis and over-treatment. However, given that only 15 cases of late dislocation are diagnosed each year in Sweden (with a population of 9.5 million in 2013 and 100,000 births) the case for the effectiveness of clinical screening is persuasive. Dr. Hansson notes that ultrasonography is heavily utilized for monitoring the progress of treatment and this is in accordance with current practice worldwide. However, with all nations struggling with escalating health care costs it is difficult to recommend universal ultrasound screening particularly since it has not yet been proven to be a “gold standard” and in light of the central tenet of this book.

This book should be read by all Paediatric Orthopaedic surgeons, General Paediatricians, Orthopaedic trainees and Public Health officials. The clear message for North America, for example, is that the absence of a Swedish style systematic screening program leads to avoidable and costly treatment in adult life with consequent major disability for those whose DDH has been missed in infancy. How wealthy countries can ignore such a significant health issue remains an enigma but perhaps armed with the content of this book, individual Orthopaedists may become more effective advocates for clinical screening for DDH locally.

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Preface

In 2006 the US Preventive Services Task Force (USPSTF) published an article in Pediatrics entitled:

“Screening for Developmental Dysplasia of the Hip: Recommendation Statement”

The 17 members of the USPSTF concluded that: “evidence is insufficient to recommend routine screening for developmental dysplasia of the hip (DDH) in infants as means to prevent adverse outcomes (I recommend) (65).

This statement was based on a selective review of the literature and was therefore incorrect. This has had a serious negative impact on efforts to introduce a screening program for children with neonatal hip instability (NHI) in North America similar to the one which has so successfully been practised in Sweden on the maternity wards for more than 50 years.

In Sweden Sophus von Rosen and Kurt Palmén in the early 1950s started routinely to examine newborn infants on maternity wards for NHI in two separate maternity units (52, 58). Within several years they reported that:

1. They achieved high success rate in identifying children in the first few days of life who would develop subluxated or dislocated hips (“developmental dysplasia of the hip”) if not treated from birth.

2. If treatment in the original von Rosen splint is commenced during the first few days of life and monitored correctly, almost all children with unstable hips at birth will develop normal hips.

3. The risk of serious adverse effects of treatment, such as avascular necrosis of the femoral head (AVN), is extremely low when treatment in the Original von Rosen splint is commenced during the first few days of life when the splint has been applied correctly.

A nation-wide screening program for children with NHI in Sweden was soon commenced after von Rosen and Palmén had published their pioneer studies more than 50 years ago. With a population of 9.5 million and about 100,000 live births each year, the estimated annual number of late diagnosed cases of DDH if no screening was practiced on the maternity wards would be 100 – 200 cases (64). Düppe, who is now in charge of collecting data for all late diagnosed cases in Sweden, has recently reported that the mean annual number of late diagnosed cases of DDH, “missed” at the primary screening on our maternity wards during the 2000s, has been 15 cases (13). These figures have thus revealed that in about 90% of the children who developed displaced hips before the screening program was commenced the diagnosis is currently established before the children leave the maternity wards. Further, when treatment in the Original von Rosen splint in children born with unstable hips is commenced during the first few days of life and monitored correctly, more than 95% of the children will develop normal hips and AVN, as a complication of treatment, will be less than 1% when treatment in the splint is commenced this early (20, 28, 29).
The primary aim of this monograph is to present data showing that the conclusions drawn by USPSTF about screening for developmental dysplasia of the hip were incomplete and inaccurate by omitting the available literature on the unique nation-wide screening program from Sweden. With the aim of showing how significantly the screening program has improved the results when treating children for DDH, a short historical review of the results achieved prior to the introduction of the screening program has also been included.

As the reported efficacy of different braces used when treating children for NHI has varied considerably, the extreme success rate with the Original von Rosen splint, used in Sweden for more than 50 years, will also be discussed. As there is often more to learn from pitfalls than from success, special attention will be focused on how to avoid pitfalls both at primary screening for children with NHI and early treatment in the Original von Rosen splint.

There are several thousand children in the United States who develop displaced hips each year and in whom the diagnosis commonly is established late. The ultimate goal for this monograph is to contribute to change the negative attitude towards Screening for Developmental Dysplasia of the Hip on maternity wards, as presented in the USPSTF report in 2006. If this goal were to be achieved, and a “Swedish Screening program” introduced in North America, a large number of children with this hip disorder would not need to have complicated treatment in hip spica and/or with surgery, which today is the case, with the risk of less successful final results. They would instead develop normal hips with a high success rate if treated for NIH from birth in the Original von Rosen splint for 6-12 weeks with an extremely low risk of serious adverse effects of treatment such as AVN.

To enable the reader to easily and quickly get an idea about “the message of this monograph” a framed summary has been included at the end of each section.

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Terminology

The terminology used to describe hip instability in children includes:

1. Congenital dislocation of the hip joint (CDH)
2. Preluxation of the hip joint (PLH)
3. Hip at risk (HAR)
4. Developmental dysplasia of the hip (DDH)
5. Neonatal hip instability (NHI)

Comments

The term *Congenital dislocation of the hip joint (CDH)* was commonly used for children in whom “permanently displaced hips” were diagnosed late, usually after they had started to walk (61, 62). It was believed that this was a true congenital deformity which was already present at birth but was not diagnosed until later. However, Putti, as long ago as in 1929, used the term “*Preluxation of the hip (PLH)*” and believed that the displacement of the femoral head was a deformity that subsequently developed during the first few months of life (57). He also maintained, which was controversial at that time, that the chances of obtaining successful results when treating these children was best when treatment was commenced early. *Hip at risk (HAR)* is commonly used in North America rather than PLH (75). In 1987 Klisic introduced the term "*Developmental dysplasia of the hip (DDH)*", which today is commonly used, and he believed, like Putti, that displacement of the femoral head developed subsequently, rather than being present at birth (41). It is rare that the femoral head is already permanently displaced at birth but is rather unstable – displaceable – and “*Neonatal Hip Instability* (NHI) is a term nowadays commonly used when screening children on the maternity wards who later in life will develop permanently displaced hips (12, 27).

**In summary**, when screening newborn infants on the maternity wards who will develop displaced hips the appropriate term to use is “*Neonatal Hip Instability* (NHI) and when screening children after this age, when permanent displacement of the femoral head has been established, the term “*Developmental Dysplasia of the Hip*” (DDH) is appropriate and is now widely used to describe this condition.
Historical review

Closed reduction of dislocated hips by the Lorenz Technique

Adolf Lorenz (Fig. 1 A) of Vienna, Austria, was at the beginning of the last century known as one of the leading experts in Europe on the management of children with congenital dislocation of the hip joint (CDH) (62). He published a method for closed reduction of congenital dislocation of the hip joint in 1895 which, according to Severin, “was welcomed all over the world” (26, 45, 62). Lorenz claimed that retention of reduction was as important as reduction. He also gained experience with open reduction of 200 hips and saw 3 deaths and also many stiff and/or contracted hips (62). These poor results after open reduction in the pre-antibiotic era led many orthopaedic centres in the early 1900s to abandon open treatment entirely (62).

In 1920 Lorenz published his book: "DIE SOGENNANTE ANGEBORENE HÜFTVERRENKUNG” (Fig. 1B) (the so-called congenital dislocation of the hip joint), which turned out to have a significant influence on the routines for treating children with CDH at many orthopaedic centres in Europe as well as in Austria (26, 46, 62). He described in detail a number of modifications of closed reduction and claimed that the best age for treating children with CDH with closed reduction was between 2 and 3 years and the upper age for closed reduction in cases with bilateral dislocations was 5-6 years and in unilateral cases 6-7 years. Following these principles, and using his own classification for assessing his results, he reported “first class results” in 57 % of 477 unilateral cases and 53 % of 290 bilateral cases (62). The title of his book indicates that he believed that the dislocation of the femoral head was commonly not already present at birth but rather developed subsequently and therefore treatment should be postponed until two years of age. Putti shared Lorenz’s view that the dislocation develops late and used the term “preluxation” but wrote: “To my thinking, the road to be followed is a different one, that is the lowering of that age limit, which is still commonly considered the youngest suitable for beginning treatment” (57).

Lorenz was a candidate for being awarded the Noble Prize in 1923, but missed the prize because of one lacking vote (70). His son Konrad Lorenz was awarded the Noble Prize in medicine and physiology in 1973.
Patrik Haglund (Fig. 2 A) was appointed as first professor of "Orthopaedics" in Sweden in 1913 at the Orthopaedic Department at the Karolinska Hospital in Stockholm. In the early 1900s he introduced a modification of Lorenz’s method for treating children with CDH by closed reduction (26). He claimed that using this method he had achieved “permanent cures” in almost 100% of cases with unilateral dislocations but “only” in 60-70% of cases with bilateral dislocations (62). However, he did not report how he had reached these conclusions.

Severin, in 1941 in his classic thesis “CONTRIBUTION TO THE KNOWLEDGE OF CONGENITAL DISLOCATION OF THE HIP JOINT” (CDH), before screening for children with neonatal hip instability (NHI) had been introduced in Sweden, reviewed the children treated for CDH by closed reduction (at this time these children were never operated upon in Sweden) at the Orthopaedic Department at the Karolinska Hospital by Haglund (Fig. 3) (62). During the 20-year period between 1913 and 1932 there were in all 757 children with CDH admitted to this department and in all children treatment was commenced after the first year of life (Fig. 4). In 427 children (56%) the treatment was considered “unsuccessful” and in 330 (44%) “successful”. He reviewed children with 5 or more years follow up in whom treatment had initially been determined to be successful. He introduced a new classification of the assessment of the radiological results, which is still commonly used today. Of the 330 children, he was able to review 306 (93%) with 417 primarily displaced hips. Only 4.6% of the hips were classified as “well developed” and as many as 79% were either subluxated or redislocated (Fig. 4 B). In addition, serious adverse effects of treatment, such as avascular necrosis of the femoral head, were also commonly seen (Fig. 3 D). He also reported that the earlier treatment was commenced, the greater was the success rate (Fig. 4 C). These findings convinced him that Lorenz was wrong when he claimed that the ideal age for treating these patients by closed reduction was 2-3 years and his findings significantly contributed to screening for children with NHI being commenced on the maternity wards in Sweden in the 1950s.
Figure 3. A. Erik Severin (1908-1960). B. Severin’s thesis from 1941 (62). C. Hip spica applied according to Lorenz ("second Lorenz position") at treatment by closed reduction in a child with CDH. D. Result after closed reduction in one of the patients reviewed by Severin, which reveals serious adverse effects of treatment including AVN, a short femoral neck and a high-riding greater trochanter.
Before screening for neonatal hip instability was commenced on the maternity wards in Sweden in the 1950s, the diagnosis was established after the first year of life in almost all children with DDH and less than 4% of the hips “developed well” after closed reduction using a modification of Lorenz’s method.
Contributions by pioneers in the early diagnosis and treatment of children with unstable or displaced hips

There were several orthopaedic surgeons and paediatricians who early argued against Lorenz and claimed that the earlier the treatment is commenced when treating children with dislocated hips, the better the results, including Le Damany, Putti, Ortolani, Pavlik etc.

Pierre Le Damany was a French orthopaedic surgeon who in 1912 was the first to report on systematic examination of newborn infants for dislocation of the hip joint (44). In none of the children he examined did he find the clinical signs of dislocation seen in older children. Using a new clinical test, he instead found that the hips were subluxatable - “
hanches subluxables” - in 12 out of 1,500 newborn infants (Fig. 5). His test was similar to the tests later on described by Palmén and Barlow for detecting unstable but not yet permanently displaced hips in newborn infants.

Pierre Le Damany (1870-1963)

Figure 5. A. P. Le Damany’s book from 1912. B. Le Damany’s test to reveal subluxatable hips.
Vittorio Putti (1880-1949) was an Italian orthopaedic surgeon who as early as in 1929 published a paper entitled: “Early treatment of congenital dislocation of the hip joint” (57). He succeeded Professor Codivilla as Director of the world-renowned Rizzoli Orthopaedic Institute in Bologna. In children with DDH he maintained, which was a controversial statement at this time, that the chances of obtaining a successful result increased the earlier treatment was commenced.

Marino Ortolani (1904-1983), who was a paediatrician, attended medical school in Bologna, Italy and graduated in 1929. After graduation he moved to Ferrara and started working at Institut Brefortio, which was an institution for “depraved and abandoned children” (68). He specialized in paediatrics in 1933 and in 1948 he was appointed as chief of the department. In 1935 a mother came to his clinic with her 5-month-old child and told him that she had felt “a click” in the perineal region when washing the baby. He examined the child and when abducting - adducting the hip joints he could reproduce the click. Radiographs revealed a displaced hip. This made him start examining the hips of newborn infants by “the Ortolani test”, by means of which he was able to establish the diagnosis of DDH “from birth or at a very early age” (49-51). At “The Center for Diagnosis, Prophylaxis and Treatment of Congenital Hip Dislocation” he treated more than 8,000 children with “congenital hip pathology”. He retired in 1973.

Berich Frejka (1890-1972) trained at Karls University, Prag, Czechoslovakia and received his MD in 1919 (39). He was appointed member of the staff at the Orthopaedic Department in Bratislava in 1922. In 1927 he moved to Brno where he was appointed Professor of Orthopaedics in 1931. During the war the fascists forced him to leave his professorship but he was re-instated as professor in 1945 at the Orthopaedic Department at the University of Brno. His special interests were DDH and scoliosis. His ”Frejka pillow” has been used in many countries for treating children for NHI and DDH.
Pioneer Contributors

Arnold Pavlik (1902-1962) trained at the medical school in Brno, Czechoslovakia and received his MD in 1930 (7). His PhD thesis was on experimental lengthening of long bones. Professor Frejka supported his application for the position as first head of the new Orthopaedic Department in Olmouc in 1939. In 1950 he was diagnosed with “infiltrations of the lungs”, for which he was primarily treated conservatively and in 1955 also by surgery. He became known worldwide for the development of “a functional, active method of treating developmental dysplasia of the hip” by the use of the “Pavlik harness” (56).

Kurt Palmén (1912-2000), who was a paediatrician, trained at the University of Uppsala, Sweden and received his MD in 1939. In 1949 he was appointed Consultant Paediatrician at the hospital in Falköping. He introduced screening for hip instability in newborn infants on the maternity wards in Sweden in the 1950s. He also presented a clinical test for detecting unstable hips in newborn infants similar to the tests presented by Le Damany in 1912 and Palmén 1961. In 1961 he presented his Thesis: “Preluxation of the Hip” and in 1984 his Classic Acta Orthopaedica Scandinavica Supplement: “Prevention of congenital dislocation of the hip” was published (52, 54).

Thomas Geoffrey Barlow (1915-1974) trained in Manchester, England and received his B.Sc. in 1936 and qualified in 1939. His FRCS was granted in 1949. He was Consultant Orthopaedic and Trauma Surgeon at Salford Hospital in Manchester. His classic paper entitled: “Early diagnosis of congenital dislocation of the hip”, in which he presents a clinical test for revealing dislocatable but not yet permanently displaced hips in newborn infants similar to the test presented by Le Damany 1912 and Palmén 1961, was published in 1962 (6).
Hormones as etiological factors of pelvic –
and hip instability in newborn infants

NHI has been postulated as an etiological factor contributing to development of displaced hips in children during the first few months of life (52, 79). NHI has also been the basis of clinical examination for establishing diagnosis at birth in children who if not treated will later develop displaced hips. It has therefore been of interest to postulate what causes the hip instability.

As long ago as 1925, Hisaw could demonstrate in animal studies that by injecting ovarian extracts it was possible to produce pelvic instability similar to that seen in pregnant women (37). He concluded that the pelvic instability seen during pregnancy was caused by a specific hormone he called “Relaxin”. This hormone, which is a nonuniform polypeptide, is produced in animals not only in the ovaries but also in the uterus and placenta (3, 4). It is, not yet known where relaxin is produced in man. Relaxin will only cause pelvic instability if oestrogen is also present and this has been referred to as “oestrogen priming”.

Relaxin combined with oestrogen has a specific effect on bone, cartilage and connective tissue of the pelvis (3). In other parts of the body tissues are not affected by relaxin in a similar manner. Why this is the case is not yet known. The production of relaxin is significantly increased during pregnancy and it acts not only on the pelvis but also on the uterus and breasts.

In newborn children large amounts of oestradiol are excreted but this ceases after a few days. Increased excretion of both oestosterone and oestradiol has been found in children with DDH (3).

Andrén of Malmö, Sweden, who also used the term “congenital dislocation of the hip joint” also in newborn infants, studied pelvic instability both in normal children and children with congenital dislocation of the hip joint (Fig. 6) (3). He used AP-radiographs of the pelvis of newborn infants with the hips in 90 degrees of both flexion and abduction. With the hips in this position he obtained radiographs both when pushing the legs together and when pulling them apart - “push and pull technique”- (Fig. 7). The degree of pelvic instability was assessed by measuring several distances in the two pelvic views including the width of the symphysis. In newborn children with congenital dislocation of the hip joint pelvic instability was considerably increased compared to what he found in normal children. Furthermore, the instability was greater in females than in males. He concluded: “The instability of the pelvis in newborns with dislocation of the hip is so much greater than in the normal newborns that it appears to be an important sign of congenital dislocation of the hip and that the dislocability of the hips is only one of the components of pelvic instability”. Ortolani stated in 1976 : “Andrén and Borglin’s hormonal theory explained unstable hips. We do not agree with them because this theory failed to explain the existence of unilateral unstable hips” (51). Today, however, the unilateral dislocations are believed to be explained by the position of the fetus in utero during pregnancy, type of delivery etc.

Relaxin may be one of several etiological factors contributing to development of neonatal hip instability.
Figure 7. Radiographs of the pelvis in a newborn child with congenital dislocation of the hip joint obtained for demonstrating pelvic instability using the “push – and pull technique” as described by Andrén. A. When pushing the legs together a narrowed width of the symphysis is seen. B. When pulling the legs apart the width of the symphysis increases considerably, as a sign of pelvic instability (3).
Clinical tests used for screening of neonatal hip instability

Since the screening program for children with NHI was commenced in the 1950s in Sweden, only clinical examination of the hip joints has been used to identify children born with unstable hips on the maternity wards. Thus, hip ultrasonography, which is used for examining the hip joints of newborn infants in many other countries in Europe, has not been used routinely in Sweden. Paediatricians who are responsible for the general examination of newborn infants on the maternity wards pre-discharged have also been responsible for the primary examination of their hip joints since inception of the screening program (Fig. 8). The clinical findings from examining the hip joints are recorded routinely in the medical journal using a special registration document and this guarantees that all newborn infant’s hips are examined. Children judged to have “unstable hips” by the paediatricians are referred to the orthopaedic departments, where the surgeon on call usually sees the children (commonly together with a senior colleague) before they leave the maternity unit to decide whether the child needs treatment or not.

To be able to undertake the clinical examination on maternity wards in a reliable manner, a number of prerequisites have to fulfilled, including the following:

1. The primary examination on the maternity ward must be undertaken by a paediatrician familiar with examining hip joints of newborn infants.
2. The examination should preferably be performed no later than the second day of life as hip instability may soon decrease, making it more difficult to detect in a timely manner.
3. The child must be completely relaxed at the examination and force must never be used when determining if the hips are “unstable”. For this purpose, a warming device should be positioned over the examination table with the mother standing close to the child (Fig. 8). If the child is crying it is often helpful to have the baby drink “sweet solutions” (34). If this also fails to get the baby relaxed, the child must return later on for a second examination.

Figure 8. Child being examined on a maternity ward for hip instability by a paediatrician with the mother standing close to the baby. A warming device is positioned over the examination table.

The paediatricians on the maternity wards are the most suitable physicians to be in charge of the primary screening of children for NHI as they see the children during the first few days of life, when hip instability is most pronounced and easiest to detect.
Ortolani used the term “congenital hip dysplasia”. In 1937 he introduced a clinical test used to reveal displaced hips in children “from birth or at a very early age” (49). When examining the hip joints of newborn infants after having tested the range of hip abduction with both hips flexed 90 degrees, Ortolani’s test should be performed to determine if the hips are spontaneously dislocated (Figs. 9 and 10) (49, 50, 51).

Figure 9. Publications by Ortolani. A. Original paper on early clinical diagnosis of “congenital hip dysplasia,” published 1937 in an Italian journal (49). B. Paper in Clinical Orthopaedics in which he summarized 40 years experience with 8,000 children with “Congenital Hip Dysplasia”, he treated “from birth or at a very early age” (51). C. Monography from 1948.
Ortolani’s Test

Figure 10. Examination of the hip joints by Ortolani’s method. A. Primarily the femoral head on the right side is displaced dorsally out of the acetabulum. B. Gentle pressure by the index finger is applied to the greater trochanter and the hip is simultaneously abducted. C. By this manoeuvre, the femoral head is reduced into the acetabulum, producing a “click sign” when the displaced femoral head passes over the limbus and enters the acetabulum. D. The thigh is adducted and pressure by the thumb in a lateral direction is applied on the medial side of the thigh and the head is dislocated again and the “click sign” sign is produced once more.

Ortolani’s Test is used for detecting permanently displaced hips.
Both Palmén and Barlow noticed that when examining the hip joints of newborn infants the hips are commonly not currently displaced but displaceable (6, 52). They believed that many of these hips will become spontaneously displaced later on if not already treated from birth and Palmén (like Putti) used the term “Preluxation” to describe this condition. They both introduced a similar test for revealing displaceable hips (Figs. 12 and 13). After having tested the range of hip abduction with the hips flexed 90 degrees and performing Ortolani’s test to determine if the hips are spontaneously displaced, Palmén’s and Barlow’s tests should be performed to determine if the hips are dislocatable or subluxatable.

Figure 11. A. Palmén’s Thesis from 1961 (52). B. Barlow’s paper from 1962 (6).
Figure 12. Examination for neonatal hip instability by Palmén’s method. A. From the basic position with the femoral head concentrically positioned in the depth of the acetabulum the hip is adducted and pressure is simultaneously applied by the thumb in the lateral direction on the inside of the thigh. B. Dorsal pressure is then applied against the upper part of the femur and by this manoeuvre the femoral head is displaced dorsally out of the acetabulum. C-D. The displaced femoral head is reduced concentrically back into the acetabulum in a similar manner as in Figure 10.

Palmén’s Test is used for detecting subluxatable and dislocatable hips.
Barlow’s Tests

"The new-born child is laid on its back with the hips and knees flexed and the middle finger of each hand is placed over each greater trochanter”.

A.

"The thumb of each hand is applied to the inner side of the thigh opposite the lesser trochanter”.

B.

"In a doubtful case the pelvis may be steadied between a thumb over the pubis and fingers under the sacrum while the hip is tested with the other hand”.

C.

Fig. 13 Barlow’s two tests (6).

Barlow believed that Ortolani’s test in newborn infants was “not entirely satisfactory” and introduced a modification of this test (6). His test is made in the following two steps:

Step 1. Is a test similar to that of Ortolani used to reveal dislocated hips (Figs. 13 A and 13 B).

Step 2: Is a test used to reveal unstable hips which are not already dislocated but dislocatable. He describes this test as follows: “The second part of the test consists in applying pressure backwards and outwards with the thumb on the inner side of the thigh. If the femoral head slips out of the posterior lip of the acetabulum and back again immediately the pressure is released, the hip is “unstable” – that is to say the hip is not dislocated but dislocatable. In a doubtful case the stability of each joint can be further tested with the pelvis firmly held between a thumb on the pubis and fingers under the sacrum” (Fig. 13 C).

Barlow’s two Tests are used to reveal both dislocated and dislocatable hips.
Terminology used to describe clinical findings

In order to avoid misinterpretation of the clinical findings when examining hip joints in newborn infants it is essential to describe the findings in a correct manner. If this is not done, many children will be referred from maternity units to orthopaedic departments unnecessarily, resulting in considerable risk of children being treated unnecessarily in a variety of braces. Ortolani used the term “click sign” to describe when a spontaneously dislocated femoral head is reduced back into the acetabulum. “Atypical clicks” are commonly found when examining the hip joints of newborn infants, elicited from knee clicks or fascial strands at the greater trochanter (66). As these children will develop normal hips without treatment, the terms “clicks” and “clunks” should not be used in order to avoid misunderstandings and unnecessary treatment. Instead, findings at examination should include assessment of the following factors:

1. Range of hip abduction with hips flexed 90 degrees. Thus, if obvious limitation of hip abduction is present, this may be due to the hips being displaced (subluxated or dislocated) dorsally out of the acetabulum.

2. Whether the hips are dislocated but not reducible. Seen rarely in children with limited hip abduction and a negative Ortolani test.

3. Whether the hips are spontaneously dislocated and reducible. This is revealed by a positive Ortolani test.

4. Whether the hips are unstable and dislocatable. This is revealed by a positive Palmén and Barlow Test. It is essential to grade the degree of displaceability in two degrees: A. Subluxatable hips and B. Dislocatable hips.

5. Extra skinfolds on the medial side of the thighs are seen deep in the groin in children with displaced hips but are also commonly seen in children with normal hips (6). In these children displacement of the hips must therefore be ruled out both by using the Ortolani Test and by documenting that there is no restriction of hip abduction on either side.

Examples of referral text

1. "When examining the hip joints no extra skinfolds are seen on the medial side of the thighs. With hips flexed 90 degrees on both sides, it is primarily only possible to abduct the right hip about 45 degrees and when applying gentle pressure by the index finger at the greater trochanter and simultaneously abducting the hip one can feel how the femoral head enters the acetabulum, i.e. positive Ortolani’s Test. On the left side it is possible to abduct the hip about 70 degrees and the Ortolani, and Palmén-Barlow’s Tests are negative. Positive family history DDH – cousin."

2. "When examining the hip joints extra skinfolds are seen on the medial side of the right thigh. With the hips in 90 degrees of flexion on both sides, it is possible to abduct hips about 70 degrees. The Ortolani test is negative on both sides. The right hip is dislocatable, i.e. positive Palmén and Barlow’s Test, and the left hip is subluxatable but not dislocatable. No family history DDH."

If this terminology is used: 1. It will help junior doctors to learn to examine the hip joints of newborn infants. 2. Misinterpretation will be avoided. 3. It will make the primary screening more efficient and considerably fewer children will be treated unnecessarily.

Using terms like “clicks” and “clunks” is confusing. Instead, describe if the hips are dislocated and reducible or dislocatable/subluxatable but not spontaneously displaced.
Registration document to be used in medical records at assessment of clinical findings at examination of hip joints in newborn infants

**Patient**

Family name:__________________________________________

Gender    female ☐    male ☐

Date of birth (YYYYMMDD):___________________    Birth weight: __________

**Risk Factors for DDH**

- Family history DDH ☐
- Breech presentation ☐
- Foot deformity ☐
- Oligohydramnion ☐

**Clinical findings - maternity ward**

Date (YYYYMMDD):_____________________

Age of patient (days):_____________

Examiner:_________________________________________

<table>
<thead>
<tr>
<th>Clinical findings</th>
<th>Right hip</th>
<th>Left hip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra skinfold thigh</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Limited hip abduction</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Dislocated hip</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Dislocatable hip</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Subluxatable hip</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

**Clinical findings - orthopaedic department**

Date: (YYYYMMDD)_____________________

Age of patient (days):_____________

Examiner:_____________________________________________________________________

<table>
<thead>
<tr>
<th>Clinical findings</th>
<th>Right hip</th>
<th>Left hip</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra skin fold thigh</td>
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</tr>
<tr>
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<td>☐</td>
</tr>
<tr>
<td>Dislocated hip</td>
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</tr>
<tr>
<td>Dislocatable hip</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Subluxatable hip</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Hip ultrasonography

Hip ultrasonography (US) is a non-invasive technique, introduced by Reinhold Graf in the 1980s, which provides essential information about the immature and incompletely ossified hip in newborn infants not visible on regular plain radiographs (Figs. 14 and 15) (23). Several techniques are used which can be divided into: 1. static and 2. dynamic techniques (9, 18, 23, 32, 33). The first of these techniques is used for assessment of the development of the acetabulum and how well the femoral head is covered by the acetabulum with the hip in the neutral position. Using the second technique, with the aim of assessing the degree of hip instability, a “provocation test” (Palmén-Barlow’s test) is used simultaneously as the ultrasonograms are obtained.

Figure 14. A. Reinhard Graf teaching. B. Graf and Schuler’s textbook on Hip Sonography (23).

Static ultrasonography

Figure 15. A. Static ultrasonograms obtained according to Graf. With the child in the lateral position in “a positioning sling”, the transducer is positioned over the trochanter region. B. Normal hip with visible femoral nucleus and femoral head well covered by a normal acetabulum. C. A poorly developed acetabulum and 2/3 of the non-ossified cartilaginous femoral head is uncovered by the acetabulum (Graf III Hip).
Routines for how ultrasonography (US) should be used for screening and treating children with NHI has not yet been established in a convincing manner. In central Europe it has been claimed that for a successful screening program all children should have US (32). Whether the US shall be obtained before the children leave maternity wards, or later, when hip instability may have regressed spontaneously, with the aim of avoiding false positive findings still also seems to be a matter of controversy (32). When using US there frequently seems to be a risk for difficulty in separating “immature hips”, which will develop normally without treatment, from hips which will develop true dislocations if not treated from birth. Thus, there is also a risk of considerable “over diagnosis” when US is used on maternity wards for primary screening of children for DDH.

![Figure 16. Theses from Sweden on Dynamic Ultrasound examination of hips in newborn infants. A. H Dahlström 1989. B. T Finnbogason 2008.](image)

When ultrasonograms of the hips are obtained in newborn infants both static and dynamic views should be used.
**Dynamic hip ultrasonography**

When dynamic ultrasonograms of the hips in newborn infants are obtained the transducer is positioned anteriorly at the hip joint and simultaneously a “provocation test” using Palmén’s- Barlow’s tests is performed to reveal hip instability (18). Usually two examiners participate, one positioning the transducer and one performing the provocation test. However, the examination can also be performed by only one examiner when a special table is used with a transverse armature over the table used for fixation of the transducer (18).

Using this technique an anterior oblique sagittal view of the hip is obtained. In this view the anterior rim of the acetabulum is seen as well as the femoral head and neck (Fig. 17 A). Prerequisites for obtaining reliable views include that the examiner performing the provocation test is familiar with examining the hip joints of newborn infants for hip instability and that the child is completely relaxed at the examination and no excessive force should be necessary when testing for instability. The severity of hip instability was used to be primarily graded by visual assessment but is currently more commonly measured on the screen (Fig. 17 B).

![Figure 17](image-url)

**Figure 17.** A. Anterior dynamic ultrasonogram. a= anterior acetabular rim, b= posterior acetabular rim, c= femoral head, d= Femoral neck/diaphysis. I. Hip in neutral position. II. Unstable hip in subluxated position. III. Unstable hip in dislocated position. B Measurement of degree of displacement of the femoral head on dynamic ultrasonogram (from Finnbogason 2008).
Holen et al concluded: “When clinical screening is of high quality the effect of an additional ultrasound examination, measured as late-presenting hip dysplasia, is marginal” (38).

Engesaeter et al, when examining 100 newborn infants at high risk of hip instability, concluded: “Dynamic assessment of stability was the only ultrasound technique that had a significant relation to outcome” (16). Terjesen et al followed 306 children from birth who primarily received no treatment and who had been judged to have normal hips primarily at clinical examination but in whom dynamic ultrasonograms had been assessed as pathological (73). At 4-5 months of age 291 of these children had developed normal hips and 15 children, four of whom had a family history of DDH, had developed abnormal hips but none had developed a frank dislocation. All these 15 children developed normal hips after treatment in an abduction splint commenced at 4-5 months of age. They concluded: “Newborn infants with abnormal and suspicious ultrasound findings who are normal on clinical examination do not need treatment from birth; most of these hips will settle spontaneously. Treatment can be postponed until the age of four to five months unless clinical instability develops or ultrasound shows dislocation”.

The experience gained from Sweden, where US is not used routinely at screening of newborn infants for NHI, and studies from Norway, where the efficacy of US as a tool used at screening of these children has been studied extensively (38, 73), suggests that the following conclusions can be drawn about the use of US when screening these children and subsequently during treatment in braces:

1. When paediatricians familiar with neonatal hip examination carry out the hip examination ultrasound will not reduce the number of missed DDH cases.

2. When US is used in newborn infants both static and dynamic views should be obtained.

3. If there is obvious disagreement about the clinical findings as assessed by the paediatricians and orthopaedic surgeons, US may be a helpful tool to determine if the child needs treatment in a brace.

4. In newborn children with a family history of DDH and no obvious hip instability it is advisable to obtain US of the hips as a routine no later than at the age of four weeks.

5. To detect residual displacement of the femoral head after initial brace treatment in infants judged to have unstable hips at birth, which is difficult to detect by clinical examination, US (static views) should be obtained routinely after about 6 weeks’ treatment.

6. US obtained after 6 weeks’ treatment in the Original von Rosen splint is helpful to determine if the child should be treated in the splint for an additional 6 weeks.
Screening at Child Health Clinics

In Sweden all children are seen at Child Health Clinics by a physician four times during the first year of life for a routine control of general health. With the aim of picking up children who have developed displaced hips and who had been “missed” at the primary examination on the maternity wards, Palmén advocated that the examination of the hip joints should routinely be repeated at these visits.

After the neonatal period (first month of life) the clinical findings of infants with DDH differ from those seen in children with unstable hips at birth. While many babies’ hips will have spontaneously reduced and stabilised, the initial instability of some children’s hips may have progressed to permanent displacement, either to fixed subluxation or to frank dislocation. At this age the diagnosis may therefore be established by either or both of the following two clinical findings: 1. Limited hip abduction (Fig. 18) and/or 2. A positive Ortolani Test (Fig. 10).

![Figure 18. After the neonatal period limited hip abduction is a common clinical finding in children with displaced hips – in this child on the left side (Netter illustration from www.netterimages.com. Elsevier Inc. All rights reserved).](image)

Children who have developed bilateral dislocations, seen in 40% of all children with DDH, missed at the primary screening on the maternity wards are more difficult to pick up at the Child Health Clinics than children with unilateral dislocations due to the fact that in these children there is no “normal side” for comparison (62). Thus, it is advisable to liberally obtain ultrasonograms of the hips up to the age of four months and after this age radiographs of the hips in children seen during the first year of life with bilateral limitation of hip abduction to 45 degrees or less for the purpose of ruling out bilaterally displaced hips.

*Extra skinfolds* on the medial side of the thighs in the groin have been thought to be a sign in children with displaced hips. As this is also commonly seen in children with normal hips, children in whom extra skinfolds are seen in combination with limited hip abduction and/or a positive Ortolani test should have ultrasonograms or radiographs of the hips (6).

(*Limited hip abduction is a common clinical finding at diagnosis of children with displaced hips after the neonatal period.*)

(*In children seen after the neonatal period with bilateral limitation of hip abduction to 45 degrees or less ultrasonograms or radiographs should be obtained to rule out bilaterally displaced hips.*)
Efficacy in Sweden of the screening program for neonatal hip instability

Review of the efficacy of a screening program for children with NHI on the maternity wards must include:

1. Assessment of local incidence of DDH
2. Data about all children “missed” on the maternity wards
3. Review of results in children treated for NHI
4. Assessment of adverse effects of treatment in braces/splints such as AVN

*If the number of late diagnosed cases remain high one can not rule out the possibility that a large number of children treated for NHI would have developed normal hips without treatment, giving a false impression of the results being more successful than in fact has been the case.*

The efficacy of the screening program for children with NHI on the maternity wards in Sweden has been reviewed both locally at a number of university hospitals (Fig. 19) (1, 19, 27) as well as nationwide when collecting data for all “missed cases” of DDH in Sweden (13, 54) (Fig. 21). Palmén for many years was in charge of collecting data of all “missed cases” of DDH in all of Sweden. He presented data covering the years 1948 - 1960 and 1973 - 1979. Henrik Düppe, who took over this responsibility in 2000 will publish his data in the near future (13).

**Incidence of DDH in Sweden**

Severin studied the incidence of DDH in children in Sweden (64). He collected data for all children with “CDH” who had been admitted to the orthopaedic departments BEFORE screening for children with NHI was commenced. He found that the incidence was 0.9 per thousand live birth. However, he was aware that this has to be “a minimum figure” as he probably only included children with frank dislocations of the femoral head and some of the patients with subluxated and dysplastic hips were probably missed in his study.

Among the children with NHI, there may be children who will not develop frank dislocations if not treated but rather subluxated and dysplastic hips. These children are known to run an increased risk of developing degenerative arthritis of the hip as young adults and should be included when estimating the local incidence of DDH (77). An exact figure for the incidence when including these two groups of children is not yet possible to calculate. However, it seems reasonable to estimate the incidence of DDH in Sweden when including these children to be 1-2 children per thousand live births.

*The incidence of DDH in children in Sweden has been estimated to 1-2 children per thousand live births.*
Figure 19. Publications on screening of children for neonatal hip instability from Sweden.
Cases “missed” at the primary screening on the maternity wards

The number of late diagnosed cases of DDH in Sweden has steadily decreased since the screening program for children with NHI was introduced on the maternity wards in the 1950s (Fig. 21). Currently, there are on average 15 late diagnosed cases each year. During the 9-year period 2000 - 2008, when 901,788 children were born in Sweden, altogether 116 children with DDH were “missed” at the primary screening on the maternity wards (0.12 per thousand live births) (Figs. 20 and 21) (13). If no screening had been practiced on the maternity the estimated number of late diagnosed cases of DDH would have been altogether 1,000 - 2,000 during this 9 year period (1-2 per 1,000 live births). These figures confirm that in about 90 % of the estimated number of children with DDH in Sweden, the diagnosis is at present established before the children are discharge from the maternity wards.

Figure 20. Live births in Sweden, 1948-2008.

Pitfalls in the early diagnosis of children with NHI on the maternity wards

In reviewing the literature on screening of children for NHI on the maternity wards from Sweden and also from other countries the number of “missed” children has varied (Tables 1 and 2). The most successful results have been presented from Malmö, where Professor von Rosen was head of the Orthopaedic Department from 1940 to 1965. Among 58,759 live births in Malmö, only 4 cases of DDH were diagnosed late, indicating that in about 95% of the children with DDH the diagnosis was established on the maternity wards (20). Similar results, although not quite as successful as reported from Malmö, have also been reported in other studies from both Sweden and the UK (Tables 1 and 2). Nevertheless, children with DDH, even if in small numbers, continue to escape detection on maternity wards and in no study so far has the diagnosis been established in all children with DDH on maternity wards. Factors which may contribute to cases still being missed on the maternity wards include the possibility that the hip examination may have been overlooked or inexperienced examiners have been in charge of the screening.

Table 1. Number and incidence of “missed cases” in studies on neonatal screening for children with DDH in Sweden.

<table>
<thead>
<tr>
<th>Author</th>
<th>Live births</th>
<th>Missed cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fredensborg (1975)</td>
<td>58,759</td>
<td>4</td>
</tr>
<tr>
<td>(Malmö 1956-1972)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palmén (1979)</td>
<td>417,000</td>
<td>22</td>
</tr>
<tr>
<td>(all of Sweden 1973-1979)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hansson et al (1988)</td>
<td>65,875</td>
<td>11</td>
</tr>
<tr>
<td>(Göteborg 1961-1970)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Düppe &amp; Danielsson (2002)</td>
<td>132,601</td>
<td>21</td>
</tr>
<tr>
<td>(Malmö 1956-1999)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Düppe (2012)</td>
<td>901,788</td>
<td>116</td>
</tr>
<tr>
<td>(all of Sweden 2000-2008)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Number and incidence of “missed cases” in studies on neonatal screening for DDH from countries outside Scandinavia.

<table>
<thead>
<tr>
<th>Author</th>
<th>Live births</th>
<th>Missed cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finlay et al (1967)</td>
<td>14,594</td>
<td>1</td>
</tr>
<tr>
<td>Mitchel (1972)</td>
<td>31,961</td>
<td>4</td>
</tr>
<tr>
<td>Galasko (1979)</td>
<td>11,980</td>
<td>10</td>
</tr>
<tr>
<td>Monk (1979)</td>
<td>25,263</td>
<td>7</td>
</tr>
<tr>
<td>Sommerville (1979)</td>
<td>82,000</td>
<td>31</td>
</tr>
</tbody>
</table>

In 90% of the children with DDH in Sweden, the diagnosis is established on the maternity wards.
Failure to perform hip examination on the maternity wards

In Gothenburg, Sweden, among 65,875 live births, 20 children with DDH were “missed” at the primary screening on the maternity wards (27, 29). Of these children, 11 (55%) had a birth weight below 2,500 grams and/or had been treated at the neonatal intensive care unit (Fig. 22). A reasonable explanation for why the diagnosis was delayed primarily in these 11 children could, at least in some cases, have been that the paediatricians overlooked examination of the hip joints because of attention to more urgent life-threatening problems.

In addition, every second child missed during this period were born during weekends. These 10 children might have been “missed” because paediatricians were not available on the wards during weekends or because the hip examination was delayed until an age when the clinical findings are more difficult to assess correctly.

<table>
<thead>
<tr>
<th>Author</th>
<th>Live births</th>
<th>Missed cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Per 1,000 Live births</td>
</tr>
<tr>
<td>Finlay et al (1967)</td>
<td>14,594</td>
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<td>Galasko (1979)</td>
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<td>Monk (1979)</td>
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</tr>
<tr>
<td>Sommerville (1979)</td>
<td>82,000</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 2. Number and incidence of “missed cases” in studies on neonatal screening for DDH from countries outside Scandinavia.

**Figure 22.** Child treated at the neonatal intensive care unit in an incubator.

*It is essential not to overlook examination of the hip joints in children treated at the neonatal intensive care unit and in children born during weekends.*
Inexperienced examiners

Both in Malmö and in Gothenburg, a limited number of senior paediatricians were in charge of examining the hip joints of the newborn infants on the maternity wards for a number of years when the screening program for children with NHI was commenced in the 1950s. In fact, in Malmö one paediatrician - Doctor Selander – was responsible for the screening of these children for almost 10 years. During this period both the number of newborn infants assessed to have unstable hips and the number of “missed cases” of DDH was low both in Malmö and in Gothenburg (Table 3 and Fig. 23 B). Later on, in the mid 1960s, the number of paediatricians involved in the screening program increased both in Malmö and in Gothenburg. When this happened, the number of children assessed to have unstable hips increased considerably in both Malmö and Gothenburg and simultaneously almost every second child with DDH was missed at the primary screening on the maternity wards (Table 3) (Fig. 23 B). After reorganization of the routines for screening on the maternity wards in Malmö in the 1990s, both the number of children assessed to have unstable hips and “missed” children again dropped considerably (12.95 and 0.07 per thousand live births respectively).

Figure 23. Screening for neonatal hip instability in Gothenburg 1961-1970. A. Live births (65.875). B. Children with suspected NIH according to the pediatricians (blue line - 1.102) and children assessed to have unstable hips according to the orthopaedic surgeons (red line - 471) (Hansson 1980).
Table 3. Number of “missed” cases of DDH at the primary screening on the maternity wards in relation to live births and newborn infants assessed to have unstable hips in Gothenburg, Malmö and Lund.

<table>
<thead>
<tr>
<th>Year</th>
<th>Live births</th>
<th>Referred cases</th>
<th>Late diagnosed cases of DDH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Per 1.000</td>
<td>Number</td>
</tr>
<tr>
<td></td>
<td>Live births</td>
<td>Live births</td>
<td></td>
</tr>
<tr>
<td>Gothenburg (1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1961 - 1965</td>
<td>32,952</td>
<td>314</td>
<td>9.53</td>
</tr>
<tr>
<td>1966 - 1970</td>
<td>33,264</td>
<td>788</td>
<td>23.39</td>
</tr>
<tr>
<td>Malmö (2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1956 - 1972</td>
<td>58,759</td>
<td>548</td>
<td>9.33</td>
</tr>
<tr>
<td>1980 - 1989</td>
<td>25,468</td>
<td>807</td>
<td>31.69</td>
</tr>
<tr>
<td>1990 - 1999</td>
<td>29,799</td>
<td>386</td>
<td>12.95</td>
</tr>
<tr>
<td>Lund (3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1988 - 1997</td>
<td>32,171</td>
<td>247</td>
<td>7.68</td>
</tr>
<tr>
<td>Total</td>
<td>212,413</td>
<td>3,090</td>
<td>14.55</td>
</tr>
</tbody>
</table>


When paediatricians with limited experience of examining the hips in newborn infants are in charge of the screening of children for neonatal hip instability on the maternity wards both the number of cases referred for suspected hip instability and the number of “missed cases” of DDH will increase.
Spontaneous resolution of hip instability

Barlow was the first to report that hip instability in newborn children commonly resolves spontaneously during the first week of life (62). He examined a total of 9,289 children for hip instability. Half of the children were examined during the first 3.5 days of life and the remaining half at the age of 3.5 to 7.0 days. The number of unstable or dislocated hips in the two age groups was 112 and 47 respectively. According to Barlow, the smaller number of unstable or dislocated hips in the older age group was due to spontaneous resolution of hip instability. Similar results have been reported from Gothenburg (27).

These figures are interesting for two reasons. Firstly, because children with remaining “minor hip instability” after some time may probably still run an increased risk of developing dysplastic hips, which later on may lead to early degenerative arthritis (77). Secondly because remaining minor hip instability at the end of the first week of life is often more difficult to detect than pronounced hip instability seen during the first few days of life. Thus, there may be a risk that more children are “missed” when screening children for NHI on is performed at the end of the first week rather than during the first two days of life.

With the aim of not “missing” children with unstable hips when screening children for NHI, who may need treatment and/or careful follow-up, it is essential that the initial examination of the hip joints is performed no later than the second day of life.

Children “at risk” of developing displaced hips

Several “risk factors” have been used with the aim of identifying a subgroup of children who run an increased of developing displaced hips including:

1. A family history of DDH
2. Breech presentation
3. Foot deformities
4. Intrauterine crowding

These risk factors must always be asked for when screening children for DDH both on maternity wards and at Child Health Clinics. A family history of DDH seems to be the most essential risk factor.

In Gothenburg, among 65,875 live births between 1961 and 1979, 20 children with unstable or displaced hips escaped detection at the primary screening on the maternity wards (27, 29). In five of these children (25 %) a family history of DDH was found. If the parents had routinely been asked about family history on the maternity wards, the five children might have been possible to pick up before they were discharged as newborn babies from the hospital.

In children with a family history of DDH both static and dynamic ultrasonograms of the hips must be obtained during the first days of life if no obvious hip instability is revealed at the clinical examination on the maternity wards.
Efficacy of Screening at the Child Health Clinics in Sweden

Between 1973 and 1979 a total of 707,075 children were born in Sweden. Palmén collected data for the age at diagnosis in all 407 children with DDH, including 78 children with “hip dysplasia”, who had been “missed” at the primary screening on the maternity wards during this period (54). In the majority of these children the diagnosis had been established at the Child Health Clinics and 303 children (81%) had been referred to the orthopaedic departments during the first 6 month of life, when the results of closed reduction in the majority of cases still remain quite successful (Fig. 24). The “secondary screening” at the Child Health Clinics, practiced in Sweden since 1950s, as a complement to the primary screening on the maternity wards have thus contributed significantly in improving the results for these children.

If US had been used in diagnosing these 407 children “missed” at the primary screening on the maternity wards during this seven-year period, 1.4 million hips would have had to be examined. In Sweden the estimated cost for this would be 70 million US dollars (100 US dollars per child) with no guarantee that ultrasonography as a primary method in addition to clinical examination would have diagnosed these on average 15 infants “missed” each year on the maternity wards.

**With these figures, and considering that that in more than every second infant “missed” at the primary screening on the maternity wards the diagnosis is established during the first six month of life, it is not justified to spend 10 million US dollars each year on hip ultrasonography with the aim of trying to increase the efficacy of the primary screening on the maternity wards of children with DDH.**

![Figure 24. Age at diagnosis for 407 children in Sweden with late diagnosed DDH 1973-1979 (54).](image)

By clinical examination of the hip joints during the first 6 months of life, the majority of children with DDH “missed” at the primary screening on the maternity ward can be picked up.

With the aim of trying to establish the diagnosis by ultrasonography at birth in the on average 15 children with late diagnosed DDH “missed” each year at the primary screening in Sweden, about 220,000 hips would have to be examined by ultrasonography annually, at a total cost of about 10 million US$. 

35
Abduction braces for newborn infants with unstable hips

Several different types of abduction braces are used when treating newborn infants for hip instability (NHI) (Fig. 25).

von Rosen splint  Pavlik harness  Frejka pillow
Craig splint  Tübinger Splint  "Mini-Splint"
Barlow splint  Browne splint

*Figure 25. Abduction braces used for treating newborn infants for neonatal hip instability.*
Prerequisites for a reliable brace for children with unstable hips at birth

In order to maintain concentric hip reduction reliably, an essential prerequisite for normal hip development, the hip must be held in its reduced position by the brace. To achieve this the hips must be positioned in both sufficient abduction and flexion but neither of these should be extreme. Too little abduction or flexion may lead to redisplacement; too much may cause avascular necrosis of the femoral head.

A. Hip Abduction

If sufficient hip abduction is not achieved in the brace, there is considerable risk that the femoral head may subluxate or even dislocate dorsally out of the acetabulum (Fig. 26 B). To prevent this from happening the hips must be positioned in 60-70 degrees of abduction. (Fig. 26 A).

Figure 26. Abduction positioning in braces in “the safe zone” to prevent posterior displacement of the femoral head. A. Sufficient abduction must be achieved in the splint without using any force to prevent both posterior displacement of the femoral head and AVN (Netter illustration from www.netterimages.com.©Elsevier Inc. All rights reserved.). B. CT scan of hips in a patient treated for neonatal hip instability in a Pavlik harness. On the left side the hip is positioned in far too little abduction and the non-ossified femoral head is completely dislocated posteriorly out of the acetabulum and on the right side the hip is positioned in more abduction and the femoral head with an ossified nucleus is positioned in the acetabulum.

To prevent posterior displacement of the femoral head out of the acetabulum when treating children for NHI in the Original von Rosen splint the hips must be abducted 60-70 degrees in the splint.
B. Hip Flexion

To maintain concentric reduction of the femoral head in the acetabulum, the hips must also be positioned in a sufficient amount of flexion in the brace (Figs. 27 and 28).

Figure 27. A. Radiograph of both hips obtained after 6 weeks treatment in a Frejka pillow in a child assessed to have unstable hips at birth. Residual displacement of the right hip. B. Arthrograms at 6 weeks show that, despite hip flexion of nearly 90 degrees, the right hip is dislocated and the left hip is concentrically reduced. C. With further flexion the right femoral head lies opposite the acetabulum entrance but an infolded limbus prevents deep reduction. D. Four weeks later following splintage in a hip spica with hips in over 90 degrees flexion the femoral head now lies deeply in the acetabulum and the limbus is remodelling. Conclusion: the residual displacement of the right hip seen at 6 weeks was due to the Frejka pillow not having positioned the hip in sufficient flexion and not due to intra-articular obstruction preventing concentric reduction.

Figure 28. Radiographs obtained of both hips in a child in the Original von Rosen splint treated since birth in the splint for bilateral hip instability. The left hip is dislocated due to insufficient flexion in the splint. The right hip is correctly positioned.

To prevent proximal displacement of the femoral head out of the acetabulum when treating children for NHI in the Original von Rosen splint the hips must be flexed more than 90 degrees in the splint.
Adverse effects of forced abduction in braces

It is also essential that the hips are not positioned in too much abduction. If this is done and the adductor muscles are somewhat tight (which is common in children delivered by breech) increased pressure on the cartilaginous femoral head of infancy may squeeze the vulnerable blood vessels within it and lead to avascular necrosis and possible damage to the upper femoral growth plate (8). When this happens there is a risk of lateral tethering of the physis with retarded growth of the femoral neck, horizontal tilting of the physis and also for AVN (Fig. 29).

![Radiograph of both hips in a child treated for NHI. Right hip. Mild damage to the lateral part of the upper femoral growth plate has limited its growth and, as the inner part has continued to grow, caused the femoral head to tilt sideways on the femoral neck. This may lead to a short femoral neck and later subluxation.](image)

To avoid adverse effects of treatment in the Original von Rosen splint some hip motion must be possible in the splint and forced abduction be avoided.
Potentiation of development of acetabular dysplasia by brace treatment

If the femoral head remains proximally and/or posteriorly displaced during treatment in a splint and this is not recognized for some time, acetabular dysplasia may be aggravated by the treatment in the splint. When the hips have been positioned in insufficient abduction the femoral head may subluxate posteriorly from the acetabulum, which is much more difficult to recognize than when the femoral head remains proximally displaced. When this happens, which has been reported to have occurred when using the Pavlik harness (Fig. 30) (5, 40), pressure at the posterior rim of the acetabulum increases and “posterior acetabular dysplasia” (PAD) may then develop (Fig. 26). This is a condition which is difficult to treat successfully so it is essential to use a splint in which the risk of this happening is minimal.

When using the Original von Rosen splint it is usually possible to position the hip joints in 60-70 degrees of abduction without using any force (Fig. 33). By monitoring this position of the hips during the entire period of treatment the risk of posterior displacement of the femoral head and development of posterior acetabular dysplasia will be minimal.

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Figure 30. A-B. Papers on hip dysplasia aggravated by treatment in the Pavlik harness (5, 40).
The Original von Rosen splint

Professor Sophus von Rosen
(1898-1996)

Professor Sophus von Rosen (Fig. 31) was born in 1898. He attended medical school at the University of Lund and completed his MD in 1928. He trained to become an orthopaedic surgeon at the Department of Orthopaedic Surgery in Lund 1927-1930 and at the Department of General Surgery at Kristianstad Hospital 1930-1933. In 1933, after having practiced as an orthopaedic surgeon for only three years, he was appointed as chief at the Orthopaedic Clinic (Vanföranstalten) in Härnösand in north of Sweden. He stayed in Härnösand for seven years and during these years he completed his PhD thesis entitled: “Die Infektiöse Krankheitsprozesse der Kniescheibe” (infections of the patella) Acta Orthop Scand, Suppl 3. 1939. In 1940 he was appointed as chief at the Orthopaedic Department in Malmö and retired in 1965. When in Malmö he designed the “Original von Rosen splint” (Fig. 32) in the 1950s for newborn infants with unstable hips. His first paper on the use of the splint was published in 1956 and entitled: “Early diagnosis and treatment of congenital dislocation of the joint”, Acta Orthop Scand 26:136. Introduction of his splint in Sweden dramatically improved the results of treating newborn children with unstable hips with a success rate of about 95%. He travelled internationally presenting talks on the use of his splint and became well known for his splint also outside Sweden. Professor von Rosen died at the age of 98 years in 1996.

Figure 31. Professor Sophus von Rosen.
Design of the Original von Rosen splint

The Original von Rosen splint is made of aluminium strips (thickness: 1.5 mm) and consists of a central core from which 6 “arms” project, 2 proximally, 2 laterally and 2 distally (Fig. 32). The splints are padded with foam rubber and encased in a thin layer of water-resistant washable rubber. The outer cover, being made of rubber, makes it easy for the parents to keep the splint clean and tidy during the entire treatment period.

Available sizes

It is essential to select the correct splint size: the upper “arms” should anchor the shoulders comfortably and safely; the lower “arms” should wrap under and around the baby’s thighs securely but not tightly. In addition, the splint must be frequently changed to a larger size to accommodate growth so as to achieve these two goals. The splint is available in seven sizes including:

1. Mini (160 g)  
2. Small 1 (220 g)  
3. Small 2 (245 g)  
4. Medium (300 g)  
5. Large 1 (340 g)  
6. Large 2 (530 g)  
7. Extra large (650 g)

Type of outer rubber coverage

Two types of coverage are available including: 1. Natural rubber and 2. Synthetic rubber ("Non-Latex")

Two thirds of the splits used are small-2 and medium size.
Indications for treatment in the Original von Rosen splint

Routines vary at different centers for treatment of children born with unstable hips. As hip instability often improves spontaneously rather soon after birth, it has been advocated at some centers to delay the definite decision about whether or not the child needs treatment. The reason for this being to avoid treating a lot of children born with unstable hips unnecessarily. It has also been suggested that ultrasonograms should not be obtained until the children are at least a couple of weeks old as there may be a risk of considerable overdiagnosis also when ultrasonograms are obtained during the first few days of life.

In Sweden, since the screening program for children with NHI was commenced, the decision whether or not treatment in a brace should be commenced has always been made by an orthopaedic surgeon during the first few days of life, before the children are discharged from the maternity ward. In all children with dislocated - or dislocatable hips at birth, revealed by using the Ortolani, Palmén and Barlow Tests, treatment, usually for 12 weeks, is commenced. In addition, children with “subluxatable hips”, which are displaceable but not dislocatable, are also commonly treated in the von Rosen splint for a shorter period (usually only 6 weeks). As the number of children born with unstable hips has been reported to vary between 5 and 10 per thousand live births and the incidence of “true CDH” has been estimated to be between 1 and 2 per thousand live births, in a large number of children who would not have developed subluxated or dislocated hips without treatment, treatment in the von Rosen splint is still commenced at birth (21, 52, 64). It has been speculated that this routine may reduce the number of patients developing “dysplastic hips without displacement of the femoral head” who may run an increased risk of developing degenerative arthritis of the hip at a young age. However, this assumption has not been proven.

Successful hip screening programs may unavoidably treat some children unnecessarily if we are to avoid missing the diagnosis until later in childhood.
Routine for treatment in the Original von Rosen splint

When treatment in the splint is commenced during the first few days of life we should expect the success rate to be over 95 percent (Table 4). To achieve these results it is, however, essential that a number of points are carefully observed, included the following:

1. The splint must be applied correctly (Fig. 33).

2. The children must be seen in the “Hip clinic” once a week by a nurse:
   
   A. For a bath and to rule out skin irritation after removal of the splint
   
   B. To assess if the brace has maintained the hips in the correct position and if it is time to change the brace to a larger size

3. Ultrasonograms should be obtained after 4 - 6 weeks of treatment, to ensure that the hips are developing satisfactory.

4. The parents should not be permitted to remove the splint at home.

4. The child should be kept in the supine position and not prone.

5. Decision making must be correctly applied to determine when it is time to remove the brace.

To allow hips to develop normally when using the Original von Rosen splint it is important to follow the management guidelines carefully.

A sign indicating that the splint has been correctly applied is that when the children come back for follow-up examination after 1-2 weeks for a bath and the splint is removed the children spontaneously keep their legs in more than 90 degrees of flexion and about 60-70 degrees of abduction.
Correct application of the Original von Rosen splint

Figure 33. Application of the von Rosen-splint. A. Put the child in the splint and flex the hips to more than 90 degrees. It is now possible to assess if the size of the splint is correct or needs to be changed. B. Wrap the two lower arms of the splint around the thighs with the hips flexed more than 90 degrees. C. Wrap the two mid arms towards the body. D. Wrap the two upper arms around the shoulders and try to get the ends pointing slightly towards the midline with the aim of achieving a safe anchorage of the arms. E. It is essential to leave space between the lower arms of the splint and the baby’s thighs to allow some freedom of movement.

When the Original von Rosen splint is applied correctly, the hips are positioned in more than 90 degrees of flexion, 60-70 degrees of abduction and some hip motion is allowed in the splint and forced abduction avoided.
Orthopaedic Assessment of Children referred from the Maternity Ward for Suspected Neonatal Hip Instability

Hips Dislocated or Dislocatable

Treatment
Weeks: 12

Ultrasound
Week: 6
Radiographs
Months: 4+12

Hips Subluxatable

Treatment
Weeks: 6

Ultrasound
Week: 6
Radiographs
Months: 4+12

Hips Stable

Treatment
None

Ultrasound
Week: 6
Radiographs
Month: 4

Ultrasonograms obtained at 6 weeks are used to ensure: 1. That children initially judged to have stable hips do not need treatment. 2. That hips are not displaced after 6 weeks’ treatment. 3. That 6 weeks’ treatment is sufficient in children initially judged to have subluxatable but not dislocated or dislocatable hips.

Treatment in the Original von Rosen splint lasts for 6-12 weeks depending on the degree of initial hip instability and the appearance on ultrasonograms of the hips after 6 weeks of treatment.
Monitoring of Treatment

It is essential that the treatment is monitored carefully during the entire treatment period in the von Rosen-splint, which will vary from 6 to 12 weeks (see below). The children should therefore be seen every week in the outpatient clinic by a nurse:

1. for a weekly bath as the parents are not allowed to remove the splint at home.
2. to be sure that the splint is keeping the legs in the correct position.
3. to decide when it is time to change to a larger split (7 sizes).
4. to rule out skin problems.
5. for general advice.

Detection of failure of the splint to maintain concentric reduction of the femoral head

It has been rarely reported that the original von Rosen-splint has failed to maintain concentric reduction of the femoral head in the acetabulum when treatment is commenced during the first week of life (Table 4). When this happens, however, it is essential to detect the residual displacement of the femoral head as early as possible as this will increase the likelihood that supplementary treatment will be successful.

In late diagnosed cases with displaced hips, the diagnosis is usually established by clinical examination revealing limited hip abduction (Fig. 18). However, if the child has been treated in abduction braces since the first week of life the adductor muscles will have been stretched so much that limited hip abduction is rarely seen when abduction treatment has failed to prevent displacement of the femoral head.

To detect residual displacement of the femoral head after early brace treatment, either ultrasonograms or radiographs have to be used and it is advisable that preferably ultrasonograms of the hips are obtained no later than after 4-6 weeks’ treatment in the splint.

Fig. 34. Residual displacement of the femoral head and a poorly developed acetabulum on the right side after 8 weeks’ treatment in a Frejka pillow since birth. When this radiograph was obtained the clinical findings were, however, assessed as normal. After supplementary treatment in a hip spica, this child developed normal hips.
In children for whom brace treatment was commenced at birth, Hansson found 19 children in whom primary treatment failed to prevent displacement of the femoral head (Fig. 35) (27, 29). Of these children, one was initially treated in the von Rosen-splint (one out of 160 children) and 18 in a Frejka pillow (18 out of 311 children). Most of these children had their residual displacement of the femoral head diagnosed on the first radiograph that had been obtained. Thus, in the 7 children in whom the displacement was not seen until the age of 3-4 months it would probably have been possible to recognize the displacement if the first radiographs had been obtained earlier. Furthermore, ultrasonography is now a more reliable method to reveal residual displacement than are plain radiographs during the first few months of life. Therefore, after a few weeks treatment ultrasonography is recommended to assess if the femoral head is concentrically reduced. The child in whom the displacement was not detected until at the age of 41 weeks was an “atypical case”. Initially the hips developed radiologically in a normal manner but the late displacement was probably due to the fact that she had Ehlers Danlos syndrome.

Fig. 35. Age when residual displacement was detected at radiographic examination of 19 children in whom brace treatment for NHI was commenced at birth, in one case in a von Rosen splint and in 18 with a Frejka pillow (27).

To detect residual displacement of the femoral head, which is often not possible to detect by clinical examination, ultrasonograms of the hips should be obtained no later than after 4-6 weeks’ treatment in the splint.
Children at increased risk of early failure of splint treatment

Hansson reviewed 19 children with unstable hips at birth in whom brace treatment failed to prevent displacement of the femoral head (27, 29). Of these children, 18 were initially treated in a Frejka pillow and 1 in the Original von Rosen splint. A family history of DDH was found in 9 of these children (one half of them). In attempt to identify a subgroup of children whose unstable hips at birth have greater risk of splintage failure their parents should routinely be asked whether any first order relatives have been treated for DDH.

In children with unstable hips at birth and a family history of DDH the risk of failure of early treatment is increased.

Length of treatment in the splint

The length of treatment needed in the von Rosen splint will vary with the degree of initial hip instability. von Rosen treated children in the splint routinely for 3 months (20, 50). Lauge-Pedersen et al concluded: “6 weeks treatment with the von Rosen splint is sufficient . . . .” (43). In Malmö, where von Rosen worked, dynamic ultrasonograms are currently obtained in all children referred from the maternity wards to the orthopaedic department for NHI (42). These ultrasonograms are used both to:

1. confirm that the hips are unstable and
2. decide the length of treatment in the von Rosen splint.

In children who are assessed initially to have dislocated or dislocatable hips it is advisable to treat them in the splint for 12 weeks.

In children with less hip instability, that is, when the hips are subluxatable but not dislocatable, 6 weeks’ treatment in the splint will usually be sufficient. When making the final decision for the required length of treatment beyond the initial six weeks it is advisable to have an ultrasonogram to assess the development of the hips. Thus, these ultrasonograms can be used both to:

1. reveal residual displacement of the femoral head and
2. to determine whether the hips are still dysplastic and further treatment is indicated

Some degree of “overtreatment”, having a number of children in splints unnecessarily and also treating them longer in the splint than necessary, is unavoidable if the treatment program is going to function successfully. However, the risk of serious complications, such as avascular necrosis of the femoral head (Fig. 3 D), when treatment is commenced at birth and the brace has been applied correctly is very low (approximately 1%) (21, 27, 29).

Treatment in the Original von Rosen splint takes for 6-12 weeks depending on the degree of initial hip instability and what ultrasonograms reveal after 6 weeks’ treatment.
Ultrasonograms taken after 6 weeks treatment help us to decide whether a further period of treatment is necessary.

Figure 36. Ultrasonograms of the left hip in a child assessed to have unstable hips at birth. A. The initial ultrasonogram obtained when the child was one week old revealed a dysplastic acetabulum and a poorly covered non-ossefied femoral head. B. After 6 weeks’ treatment in the Original von Rosen-splint the acetabulum has developed nicely and the femoral head is well covered. If the hips were initially subluxatable and not dislocatable and the clinical findings at six weeks of age are assessed as normal, six weeks treatment in the brace will be sufficient.

Static ultrasonograms by the Graf method
Problems which may occur during treatment
in the Original von Rosen splint

A. The splint is incorrectly applied

To ensure concentric reduction is maintained the child must be seen each week in “the hip clinic” in order to supervise correct application of the splint. The most common reason for this not being the case is that the child has grown so much so the splint has become too small and it is time to change to a larger size (7 sizes available). As the parents are not permitted to remove the splint at home, it is also essential that the parents can easily access the clinic if they have problems in keeping the child in the splint correctly.

B. Local skin irritation caused by the splint

Local skin irritation on the back and the thighs can be caused by the splint. This can usually be prevented by:

1. Washing the child in the splint every day with unperfumed soap.
2. Wiping the skin dry with a towel after washing carefully.
3. Using a thin layer of unperfumed powder.
4. Keeping the child in the prone position in the splint under observation for short periods (prone position: increased risk cot death).

Seeing the children routinely once a week in the clinic most of the “problems” which may sometimes occur during treatment in the Original von Rosen splint can be avoided by ongoing advice to the parents.

For further information about how the parents should take care of the child during the treatment period and how to transport the child by car, see the special folder designed for parents of children treated in the Original von Rosen splint.
Risk of avascular necrosis of the femoral head in children treated in the Original von Rosen Splint

Avascular necrosis of the femoral head (AVN), which is never seen in children with DDH prior to treatment, is a serious adverse effect of treatment seen after both closed and open reduction of dislocated hips (Fig. 3D) (60). No certain cure is available for AVN, which often causes patients serious problems as early as their teenage years, with pain, limping gait etc, and eventual total hip replacement, often at a rather young age with an uncertain long-term result.

The number of children in Sweden treated for NHI in the Original von Rosen splint is often 10-times the number of children treated for CDH before screening of these children was commenced on maternity wards. It has therefore been a matter of considerable concern to find out if and to what extent this “overtreatment” of children in the splint has any adverse effects and especially how great the risk of AVN will be when treatment is commenced this early.

In the newborn child, the femoral head is not yet ossified and applying forces to the head by extreme and forced positioning of the hip may have serious adverse effects on the circulation to the head and also on growth of the physis of the proximal end of the femur. It is therefore believed that at this young age the risk of adverse effects of treatment would be considerable. It has even been recommended, with the aim of reducing the risk of AVN, that when the diagnosis of DDH is established after the neonatal period treatment should be delayed until radiographs reveal that ossification of the femoral head has started and an ossified nucleus is seen on radiographs. Studies from Sweden have, however, convincingly demonstrated that on the contrary, when treatment in the von Rosen splint is commenced at birth the risk of AVN is considerably lower compared to when treatment by closed reduction is commenced later. Thus, out of 160 children in Gothenburg in whom treatment in the von Rosen splint was commenced during the first 10 days of life only one hip out of 320 hips (0.3 %) developed AVN (27). Heikkila reviewed 1100 children treated for NHI for AVN. In 180 children treated in the von Rosen splint only one hip out of 360 (0.3 %) had developed this complication (36). The low incidence of AVN in these two series is explained by the fact that during the first few days of life the hips are in the great majority of cases displaceable (“preluxation”) and if displaced are easily reduced by gentle reduction. Maintenance of concentric reduction of the femoral head in the acetabulum is at this age usually achieved in the brace without using any force. In addition, when the splint is correctly applied, some range of hip motion is possible in “the safe zone” and this will guarantee that excessive force will not be applied to the femoral head and the physis (Fig. 33). Similar results have been reported from Malmö (12, 20). In contrast, when the diagnosis is established later, the hips are frequently spontaneously displaced and at reduction of the dislocated femoral head back into the acetabulum it is often not possible without avoid applying some force. This explains why the risk of AVN is considerably higher when treatment in these children is commenced after the neonatal period. 

The risk of AVN will be less than 1 % when treatment in the von Rosen splint is commenced during the first few days of life, when hips are usually displaceable and not permanently displaced, and the splint is applied correctly allowing some hip motion within “the safe zone”.

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Results of early treatment in the Original von Rosen splint

The results of early treatment in the Original von Rosen splint have been reviewed in studies from both Sweden and the UK (Table 4). Data for 926 children treated since birth in the splint have been published to date. In only 13 (1.4%) of these children did treatment fail. The von Rosen splint has also been used successfully in Australia for many years but the results have not yet been published (25).

Heikkilä reviewed 1,100 children treated for NHI in southern Finland in the Frejka pillow or the Original von Rosen splint (36). The failure rates were for children treated in the Frejka pillow 55 out of 920 (6%) and for the children treated in the Original von Rosen splint 1 out of 180 (0.6%). He claimed that the most apparent reason for failures when using the Frejka pillow was “inappropriate control of the pillow by the parents because of their feeling pity for their baby and therefore did not place the pillow in a tight enough position and because of this the hip was dislocated on the splints”. The significant reduction of failures when using the Original von Rosen splint instead of the Frejka pillow made him conclude:

1. The splint is easy to fit.
2. The parents had no difficulties taking care of their children.
3. Problems with skin were common but fortunately not very serious.
4. A splint that can be removed by the parents cannot be recommended.

These conclusions are in accordance with what Hansson reported (27 - 30). Wenger and Rang supported theses views quoting Hensinger’s opinion that: “the Frejka pillow does not flex the hip enough to reduce DDH in difficult cases” (76). Wilkinson et al assessed the efficacy when treating 92 children for NHI in the Craig splint, the Pavlik harness and the von Rosen splint (77). The failure rate was 10 %, 25 % and 0% respectively in the three groups (Fig. 37 A).

<table>
<thead>
<tr>
<th>Author</th>
<th>Primary number of children</th>
<th>Children who received supplementary treatment</th>
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<tbody>
<tr>
<td>Finlay et al (1967)</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>Emneus and Undeland (1970)</td>
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</tr>
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<td>Mitchel (1972)</td>
<td>100</td>
<td>6</td>
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<tr>
<td>Fredensborg (1975)</td>
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<td>0</td>
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<tr>
<td>Hansson (1980)</td>
<td>160</td>
<td>1</td>
</tr>
<tr>
<td>Heikkilä (1988)</td>
<td>180</td>
<td>1</td>
</tr>
<tr>
<td>Wilkinson et al (2003)</td>
<td>24</td>
<td>0</td>
</tr>
<tr>
<td>Lauge-Pedersen et al. (2006)</td>
<td>223</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>926</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

Table 4. Review of the literature on patients treated in the von Rosen splint.

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Over 95% of the children treated for neonatal hip instability in the original von Rosen splint develop normal hips if treatment in the splint starts during the first two weeks of life and monitored correctly. The incidence of AVN should be less than 1%.
When treating children for NHI the Original von Rosen splint maintains concentric reduction of the femoral head in the acetabulum more reliably than do the Frejka pillow, Pavlik harness and Craig splint.

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**Comparison of the Frejka Pillow and the Von Rosen Splint in Treatment of Congenital Dislocation of the Hip**

Esko Heikkilä

*Aurora Hospital, Helsinki, Finland*

<table>
<thead>
<tr>
<th>Primary splint</th>
<th>Number</th>
<th>Supplementary treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frejka</td>
<td>920</td>
<td>55</td>
</tr>
<tr>
<td>Original von Rosen splint</td>
<td>180</td>
<td>1</td>
</tr>
</tbody>
</table>


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*Figure 37. Publications which assess the efficacy of different braces /splints used for treatment of children for neonatal hip instability (36, 78).*

---

When treating children for NHI the Original von Rosen splint maintains concentric reduction of the femoral head in the acetabulum more reliably than do the Frejka pillow, Pavlik harness and Craig splint.
Figure 38. Female assessed to have unstable hips at birth. A. Plain radiograph obtained during the first week of life: dysplastic acetabuli on both sides and left hip displaced. B. Static ultrasonogram of left hip according to Graf during the first week of life: poorly covered non-ossified femoral head and dysplastic acetabulum. C. Static ultrasonogram of the left hip obtained after 6 weeks’ treatment in the Original von Rosen splint: significant improvement with better coverage of the femoral head and improvement of acetabular dysplasia. D. Plain radiograph obtained at 10 weeks: no residual displacement and well developing acetabuli on both sides. E. Plain radiograph obtained at 18 months: normal development both hips with ossified femoral nuclei on both sides correctly positioned in normal acetabuli.
Case report 2

Figure 39. Female with bilateral unstable hips at birth and a family history of DDH. A. Static ultrasonogram according to Graf of the left hip obtained during the first week of life: dysplastic acetabulum and a poorly covered non-ossified femoral head (Graf: Typ III). B. Static ultrasonogram obtained after 6 weeks’ treatment in the Original von Rosen splint: significant improvement with better coverage of the femoral head and improvement of the acetabular dysplasia. C-D. Plain radiographs obtained at 8 months: normal development with ossified femoral nuclei, well developed acetabuli and the hips concentrically reduced on both sides.
Evaluation of results in all children treated for DDH in Sweden.

To date there has been no comprehensive outcome study of all children treated for DDH in Sweden. It is therefore not yet possible to present reliable results for all children treated for this hip disorder. In Table 1 I have included available Swedish data for these children used in an attempt to assess the results in all both early and late diagnosed cases of DDH. Essential data include (Table 6):

1. Estimated incidence of DDH in Sweden (1-2/1,000 live births, mean 1.5) (64).
2. Data for late diagnosed cases (15 each year, Fig. 21).
3. Results when treating newborn infants for NHI in the Original von Rosen splint (95 % success rate, Table 4).
4. Results reported from Sweden when treating late diagnosed cases of DDH (success rate 85 %, Table 5).
5. Bilateral dislocations, which have been reported to occur in 40 % of children with DDH in Sweden (62).

It is of interest to compare the results in Table 6 with the results reported by Severin in 1941, before the screening program for NHI on the maternity wards had been introduced (Fig. 4). He reported “well developed joints” in only 4 % of 417 hips in 306 children in whom treatment was commenced after the first year of life. In all these 306 children the initial treatment had been assessed as “successful” and he excluded 427 children in whom treatment had failed. The success rate of his entire series of patients must therefore have been considerably less than 4 %.

Of the 200 hips included in Table 6, only 20 hips (10 %) were hips treated in patients in whom the diagnosis had been established late and in all, treatment was estimated to have failed in 12 hips (6 %). Of these 12 hips 3 belonged to patients in whom the diagnosis had been established late. Thus, the overall success rate when taking care of these children in Sweden has dramatically improved compared to the results Severin reported 60 years ago. This is due to the efficacy of the screening on maternity wards but also due to the fact that the screening at Child Health Clinics successfully picks up the majority of children “missed” on our maternity wards at an early age (first 6 months of life), when treatment with closed reduction is still successful in the majority of these children (Table 5 and Fig. 40).

Register for cases "missed" on the maternity wards

In 2000 Henrik Düppe started to collect data for all children with DDH “missed” at the primary screening on the maternity wards in Sweden (Fig. 23) (13). He will soon present these data in a "Special hip register" and data on children treated for NHI in whom treatment has failed will also hopefully be included in this register. When these data have been collected and analysed in a few years Düppe will be able to properly evaluate our Nation’s DDH outcomes. These results will be of great value for other countries which plan to start a similar nationwide screening program for these children both on maternity wards and at Child Health Clinics.
Table 5. Treatment of late diagnosed cases of DDH at two centres in Sweden.

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Patients : 40</td>
<td>Patients : 71 (75 hips)</td>
</tr>
<tr>
<td>Age at diagnosis : 1-12 months</td>
<td>Age at diagnosis : 2-64 months</td>
</tr>
<tr>
<td>Treatment</td>
<td>Treatment</td>
</tr>
<tr>
<td>Closed reduction : 38</td>
<td>Closed reduction : 64</td>
</tr>
<tr>
<td>Open reduction : 2</td>
<td>Open reduction : 7</td>
</tr>
<tr>
<td></td>
<td>Additional surgery : 12</td>
</tr>
<tr>
<td>Results</td>
<td>Results</td>
</tr>
<tr>
<td>Patients</td>
<td>Hips</td>
</tr>
<tr>
<td>Normal hips : 38</td>
<td>Normal hips : 65</td>
</tr>
<tr>
<td>Coxa magna : 2</td>
<td>Severin II-III : 10</td>
</tr>
</tbody>
</table>
Since the DDH screening program in Sweden began on the maternity wards and the Child Health Clinics over 50 years ago the estimated success rate for treatment for these hips has improved from less than 5% to about 90%.

Table 6. Estimation of epidemiological data and results when treating children with DDH in Sweden in whom the diagnosis has been established both early and late.

A. Epidemiological data

1. Number of children born each year 100,000
2. Incidence of DDH per 1,000 live births 1.5
3. Annual number of cases with DDH 150
4. Children with bilateral dislocations 40%

B. Late diagnosed children

1. Annual number 15
2. Number of displaced hips 20
3. Estimated number of successfully treated hips (85%) 17

C. Children diagnosed on the maternity wards

1. Annual number 135
2. Number of hips which would become displaced if not treated 180
3. Estimated number of successfully treated hips (95%) 171

D. Estimation of annual results in all children treated for DDH

1. Hips treated successfully
   A. Early diagnosed children 171
   B. Late diagnosed children 17

2. Hips in which treatment failed
   A. Early diagnosed children 9
   B. Late diagnosed children 3
Summary

Undertaking a screening program for children with neonatal hip instability must involve successful primary assessment on the neonatal ward, dedicated personnel, sensible selection of a brace and proper supervision of its use.

A. How to successfully organize a screening program for hip instability in newborn infants

Sweden’s unique experience of over 50 years of neonatal screening of children born with unstable hips has been documented in many articles and theses. There remains much to be learned. We can, however, conclude that our experience detects about 90% of children who would develop dislocated hips if not treated from birth to be identified and treated promptly with high levels of success. Furthermore, the great majority of those children “missed” at birth may be identified in the first few months of life at the Child Health Clinics when closed reduction is still possible for most.

“The Swedish experience” has taught us that to be able to diagnose about 90% of the children with NHI on the maternity wards the following points have to be considered:

1. The most essential point is that the paediatricians in charge of examining the hip joints of newborn infants are trained in using the Ortolani, Palmén and Barlow Tests.

2. Examination of the hip joints should be undertaken during the first two days of life. After this age the clinical findings are more difficult to assess correctly.

3. The child must be completely relaxed during the examination and a heating device should be positioned over the examination table.

4. It is advisable to obtain ultrasonograms of the hip joints of all children with a family history of DDH, including both static and dynamic views of the hips.

5. It is essential to remember to examine the hips of children treated at the neonatal intensive care units and children born during weekends.

6. Clinical screening alone is sufficient for routine screening during the first two days of life.

7. Ultrasonograms are necessary only for special indications, such as when the paediatricians and orthopaedic surgeons disagree about the clinical findings.

Responsibility for neonatal screening of children with NHI must be given to trained paediatricians familiar with examining the hip joints of newborn children. The examination should be performed within the first 48 hours when hip instability is most easily demonstrated.
B. How to successfully monitor treatment in the Original von Rosen splint

The Original von Rosen splint, which was designed ONLY for newborn infants with NHI, has been documented in several studies to be a reliable brace for these children.

In order to achieve a success rate of over 95 % and less than 1% risk of development of AVN when using the Original von Rosen splint, which has been achieved both in Malmö and Gothenburg, the following points must be considered:

1. The splint must position the hips in more than 90 degrees of flexion and 60 - 70 degrees of abduction.

2. To prevent adverse effects of treatment such as AVN, some hip motion must be possible in the splint and forced abduction avoided.

3. The parents must not be allowed to remove the splint at home.

4. The child should be seen in “the hip clinic” once a week by a nurse to check that the splint is correctly applied, decide when it is time to change the splint to a larger size, ensure that no “skin problems” have occurred and for the child have a bath.

5. The parents must be able to easily get in touch with a nurse in the hip clinic by telephone if they are having problems with keeping the child in the splint.

6. After 6 weeks of treatment, the child must be seen again by a physician and static ultrasonograms of the hips be obtained to rule out the possibility that the hips are still displaced (which is extremely rare and often not possible to detect by clinical examination). These ultrasonograms can also be used as a tool to decide if the child should be treated for 6 or 12 weeks in the splint.

7. In children who were primarily assessed to have subluxatable but not dislocatable hips 6 weeks treatment is usually sufficient.

8. In children who were primarily assessed to have dislocated or dislocatable hips, it is usually advisable to treat the child for 12 weeks.

9. Children with unstable hips and a family history of DDH also need to be treated for 12 weeks in the splint.

10. Final radiographs of the hips should be obtained after the child has started to walk but no later than at 1.5 years of age.

The 6-12 week treatment regime may seem hard for and infant’s parents to follow. Compared with the complexities and risks of later diagnosis and treatment, however, it is relatively straight-forward and the advantages of neonatal treatment in the Original von Rosen splint cannot be over-emphasized.
Acknowledgement

First I would like to thank Anders Holmén, with whom I have worked for more than 20 years with different research projects, for once more spending many hours together with me at the computer to get this monograph completed. Henrik Düppe kindly allowed me to include data on late diagnosed cases of DDH in Sweden, which he has collected since 2000.

I remain truly grateful to Mr Michael Benson, Oxford, Professor Ian Goldie, Stockholm and Professor John Wedge, Toronto for reviewing the manuscript and for their valuable comments. Professor Wedge kindly also wrote the Foreword.

I also remain thankful to three late professors who had a very significant influence on me when deciding to choose the medical profession and/or during my training to become a paediatric orthopaedic surgeon.

Professor Erik Severin (1908-1960) was a close friend of my family when I grew up. His classic thesis on “CDH” from 1941 in significant manner contributed to the fact that screening for hip instability in newborn infants was introduced in Sweden in the 1950s. It was largely due to his influence on me as a teenager that I later decided to enter the medical profession and became a paediatric orthopaedic surgeon. Sadly, he died at the age of only 51 years in 1960.

Professor Bertil Stener (1920-1999) was my first chief when I started working as a resident in his department in Gothenburg in 1973. He was one of the leading orthopaedic tumour surgeons in the world. Without his kind help and generous support it would not have been possible for me to complete my thesis on screening for hip instability in newborn infants in 1980 and later on spend time in both Toronto and Chicago to train to become a paediatric orthopaedic surgeon.

Professor Robert B Salter (1924-2010) was known worldwide for his outstanding contributions on the management of children with “CDH”. I trained with him as his “Clinical Fellow” at The Hospital for Sick Children in Toronto in 1981. “Sick Kids” was and still is renowned as one of the world’s leading institutions for taking care of children with orthopaedic disorders. Every day working with him was a fascinating experience and I have never picked up as much knowledge in such a short time as I did when I had the privilege of working with him.

Thröstur Finnbogason kindly allowed me to include Figure 16 from his thesis from 2008. Figure 6 have been published by permission of Acta Radiologica, Figure 12 by permission of Journal of Bone and Joint Surgery Br and Figures 17 and 25 A by permission of Elsevier.

Särö
August 2013

Göran Hansson
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