Good long-term outcomes of the hip Chiari osteotomy in adolescents and adults with hip dysplasia: a systematic review

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Background and purpose — The Chiari osteotomy was a regular treatment for developmental hip dysplasia before it became mostly reserved as a salvage therapy. However, the long-term survival of the Chiari osteotomy has not been systematically investigated. We investigated the survival time of the Chiari osteotomy until conversion to total hip arthroplasty (THA) in patients with primary hip dysplasia, and factors which correlated with survival, complications, and the improvement measured in radiographic parameters.

Patients and methods — Studies were included when describing patients (> 16 years) with primary hip dysplasia treated with a Chiari osteotomy procedure with 8 years’ follow-up. Data on patient characteristics, indications, complications, radiographic parameters, and survival time (endpoint: conversion to THA) were extracted.

Results — 8 studies were included. The average postoperative center–edge angle, acetabular head index, and Sharp angle were generally restored within the target range. 3 studies reported Kaplan-Meier survival rates varying from 96% at 10 years to 72% at 20 years’ follow-up. Negative survival factors were high age at intervention and pre-existing advanced preoperative osteoarthritis. Moreover, reported complications ranged between 0% and 28.3 %.

Interpretation — The Chiari osteotomy has high reported survival rates and is capable of restoring radiographic hip parameters to healthy values. When carefully selected by young age, and a low osteoarthritis score, patients benefit from the Chiari osteotomy with satisfactory survival rates. The position of the Chiari osteotomy in relation to the peri-acetabular osteotomies should be further (re-)explored.

Patients with developmental dysplasia of the hip (DDH) are prone to develop osteoarthritis (OA) of the hip at a young age (1). A variety of osteotomy procedures have been described to prevent secondary OA and to relieve pain, including the Chiari pelvic osteotomy, which distinctively augments the dysplastic acetabulum by transverse medial displacement made just proximal to the acetabular rim. The effective lateral displacement of the superior iliac fragment covers the femoral head, creating support for the capsule, increasing hip stability, enlarging the effective weightbearing surface, and increasing hip joint stability (2-4).

Chiari osteotomy historically has been considered a reasonable mainline treatment option for acetabular dysplasia (2). In recent decades, however, as powerful acetabular redirection osteotomies and total hip replacements have proved effective, the Chiari osteotomy has become a salvage option, limited to use in very severe dysplasia or in hips with aspherical femoral heads (5). However, redirection osteotomies can be quite invasive (6) and total hip replacements may need (multiple) revisions, especially when placed in young and active patients (7). Therefore, procedures that can postpone a total hip replacement, such as the Chiari osteotomy, should be reconsidered, though no recent joint survival analysis has been performed, as is done for other hip dysplasia treatment options, e.g., the “shelf arthroplasty” (8) and the “redirectional (peri-acetabular) osteotomy” (6), nor is there a clear consensus on indications for Chiari osteotomy (5,9).

Thus, the primary aim of this study was to perform a systematic review of the long-term THA-free survival of Chiari pelvic osteotomy. The secondary aim was to evaluate reported factors that correlated with survival, the surgical indications, surgical approach, reported complications, and clinical and radiological parameters.
Patients and methods

For this systematic review, the databases Pubmed, Embase, and Cochrane were searched and queried until February 2021. The term “Chiari” was separately combined with the term “osteotomy” including all known synonyms to minimize the chance of missing articles (see Supplementary data). Obtained articles were imported into a RefWorks database (https://refworks.proquest.com/). After removal of duplicates the abstracts were read and assessed as per MOOSE guidelines (10) for quality independently by 2 authors (MN, SS) (Figure 1).

Inclusion criteria were studies in the English language, human subjects aged ≥ 16 years with primary or secondary hip dysplasia treated with Chiari procedure, and a minimum follow-up of 8 years. Studies concerning ≥ 50% patients with secondary hip dysplasia, e.g., due to Down syndrome, Trevor’s disease, Perthes disease, or cerebral palsy, were excluded. Studies in which ≥ 50% of the patients received a combined dysplasia treatment, e.g., additional osteotomies, were also excluded as we considered that in those cases the influence on the results of the Chiari osteotomy is not clear. Study inclusion was done by 3 reviewers (KW, MN, SS). Cross-references were made in the bibliographies of the included studies.

Each article was reviewed independently in full text (KW, MN, SS). Items reviewed included age, sex, number of patients and hips, study type, level of evidence, number of patients who were lost to follow-up, combination with other treatments, previous operations, preoperative OA (with scale), failure as defined by the authors (see below), survival rates (conversion to THA), complications, surgical indication, and the change in hip score (with scale). The preoperative and postoperative hip parameters (center-edge angle = CEA, Sharp angle = SA, and acetabular head index = AHI) were reviewed and visualized. The Newcastle Ottawa Scale (NOS) was used to assess the quality of each study and the average between the 2 scores of the independent observers (MN and NIH) was documented (Table 1).

Preoperative OA was recorded and dichotomized between mild and advanced OA because different scales were used: the Tönnis (11), De Mourges and Patte (DMP) (12), Japanese Orthopedic Association (13), and Kellgren–Lawrence (K–L) (14). Therefore, in every scale the level that corresponds to advanced OA was identified, after which the number of patients who were in an advanced state of OA were identified (Table 1). Differences in extracted information were discussed between the reviewers and consensus was reached at all times regarding the aspect in question. Authors of included studies were not contacted in the event of missing data.

No statistics were used due to the heterogenous data available.

Funding and potential conflicts of interest

KW and HW have received research grants from the European Government through the Prosperos project by Interreg VA Flanders—The Netherlands program, CCI grant no. 2014TC16RFCB046; and KW, HW, PS from the Dutch government through the Netherlands Organisation for Scientific Research (NWO; Applied and Engineering Sciences research programme, project number 15479) in relation to the submitted work. HW has also received a research grant from the Dutch Arthritis Foundation outside the submitted work. PS has owner shares in MRIguidance B.V. not related to the submitted work. MN, SS, NIH, BW, and RS declare no competing interests.

The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.
Results

180 studies were identified, of which 8 remained after inclusion and exclusion criteria were applied. Results are summarized in Table 1. All included studies were of observational retrospective cohort design (level IV evidence), without the use of a control group.

In all cases, the osteotomy was extracapsular, located just superior to the hip joint. The osteotomy was specified as straight (15,16), curved (16-18), and in 4 studies the shape of the osteotomy was not stated (19-22). The osteotomy height was performed at 5.5–9.0 mm height from the articular surface (15,16,18,19). Furthermore, the osteosynthesis was fixated by a plate in a 1 study (17), and with Steinman pins in a second study (15).
studies specified the usage of graft material (17,19), while 1 other study only used graft material following complications of non-union (20). 5 studies combined the Chiari procedure with a varus or valgus osteotomy of the proximal femur (3.1–25%) (16,18-21), and 2 studies combined the Chiari procedure with a trochanter osteotomy (1.3–1.9%) (19,20).

Preoperative indications and negative survival factors varied widely among all 8 studies (Table 2).

All studies documented radiological angles and all studies that documented both preoperative and postoperative values found a postoperative increase in average CEA and AHI, while the SA decreased postoperatively (Figure 2). Migaud et al. (17) reported a positive relation between improved radiographic scores and postoperative function and Nakata et al. (16) reported that hips with lower angles subsequently correlated with progression to terminal OA, whereas Calvert et al. (15) reported no correlation between achieved postoperative CEA and hip score.

All articles reported the number of conversions to THA in regard to average follow-up, ranging from 1% conversions in 17 years to 40% conversions in 32 years (Table 1).

Kaplan–Meier survival analysis with radiological progression of OA as endpoint was documented in 3 studies using the Japanese Orthopedic Association scale (16,18,20). Ohashi et al. (20) analyzed 62 hips with Chiari osteotomy alone, and recorded a 84% survival rate at 10 years and 69% at 20 years. The survival rate for 24 hips using a combined Chiari procedure with a varus or valgus osteotomy was 82% and 44% at 10 and 20 years, respectively.

Nakata et al. (16) reported survival rates in 56 patients (63 hips) at 10 and 15 years follow-up of 92% and 78%. Respectively, Nakano et al. (18) analyzed 20 patients (20 hips) with labrectomy, and 11 patients (11 hips) without labrectomy at a mean age of 35 years. Survival rates for the labrectomy group were 80% at 10 years’ and 67% at 15 years’ follow-up. For the group without labrectomy this was 100% and 83%, respectively.

Kaplan Meier survival analysis with conversion to THA as endpoint (Figure 3) were documented by 3 studies (16,17,20). First, Ohashi et al. (20) reported THA as endpoint in the advanced OA group, which consisted of 17 hips in 15 patients

Table 2. Indications for the Chiari procedure and negative survival predictors as suggested by the authors

<table>
<thead>
<tr>
<th>Reference</th>
<th>Inclusion criteria</th>
<th>Significant negative survival factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calvert et al. (15)</td>
<td>Congenital hip dislocation</td>
<td>None reported</td>
</tr>
<tr>
<td>Kotz et al. (22)</td>
<td>Acetabular dysplasia</td>
<td>Age at the time of operation</td>
</tr>
<tr>
<td>Migaud et al. (17)</td>
<td>High-grade dysplasia without signs of OA</td>
<td>Age before operation</td>
</tr>
<tr>
<td>Nakano et al. (18)</td>
<td>Acetabular dysplasia</td>
<td>Reduced volume of the interposed soft tissues: capsule and the remaining labrum. Presence of labrum interposed between the new acetabular roof and the femoral head</td>
</tr>
<tr>
<td>Nakata et al. (16)</td>
<td>OA secondary to congenital subluxation or acetabular dysplasia</td>
<td>Preoperative stage of OA</td>
</tr>
<tr>
<td>Ohashi et al. (20)</td>
<td>Subluxation of the hip and OA</td>
<td>None reported</td>
</tr>
<tr>
<td>Rozkydal et al. (21)</td>
<td>DDH</td>
<td>Level of osteotomy (high or low). Severe deformity of femoral head</td>
</tr>
<tr>
<td>Yanagimoto et al. (19)</td>
<td>DDH</td>
<td>Advanced DDH. Spherical femoral head</td>
</tr>
</tbody>
</table>

CEA = center–edge angle, DDH = developmental dysplasia of the hip, OA = osteoarthritis.
with a mean age of 39 (range 11–54). The survival rate after 10 years was 88%, and 72% at 20 years. Second, Nakata et al. (16) analyzed 96 hips from 87 patients with an average age of 29 (range 16–55). Of these, 96% lasted 10 years, and 82% survived 15 years until conversion to THA. Third, Migaud et al. (17) analyzed 99 hips in 92 patients with an average age of 34 (SD 11) and found a survival rate of 84% at 10 years’ and 68% at 18 years’ follow-up. The survival rates for DMP grade 2, 3, and 4 OA were documented as 94%, 74%, and 54% at 18 years. Additionally, severe arthrosis (DMP grade 3 and 4) in combination with a positive preoperative CEA (> 0°) was significantly (p < 0.05) associated with a higher conversion to THA. 2 other studies reported non-Kaplan–Meier survival percentages with THA as failure definition. Survival ranged from 55% to 60% with a mean time interval between 17.6 and 26.0 years (21,22).

Rehabilitation outcomes and postoperative weightbearing were documented in 4 studies Postoperatively, non-weightbearing was done with a hip spica cast (16,18,21) or with crutches (21,22). Partial weightbearing started at 6 weeks (16,18,22), and full weightbearing after 12 weeks postoperatively (16,18,21).

The complication rate and the background information on the complications were reported by all articles, except for Nakano et al. (18) and Kotz et al. (22) (Table 3).

Table 3. Complications for the Chiari procedure

<table>
<thead>
<tr>
<th>Reference</th>
<th>Hips/patients</th>
<th>No of complications</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calvert et al. (15)</td>
<td>49/45</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
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<tr>
<td></td>
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<td>2</td>
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<td></td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>Kotz et al. (22)</td>
<td>80/66</td>
<td>Not specified</td>
<td>2</td>
</tr>
<tr>
<td>Migaud et al. (17)</td>
<td>89/82</td>
<td>Not specified</td>
<td>1</td>
</tr>
<tr>
<td>Nakata et al. (16)</td>
<td>96/87</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Nakano et al. (18)</td>
<td>31/31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ohashi et al. (20)</td>
<td>103/93</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Rozkydal et al. (21)</td>
<td>130/130</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Yanagimoto et al. (19)</td>
<td>74/69</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Discussion

This study reviews survival rates after the Chiari procedure and aimed to evaluate factors that influence survival, and reported indications, complications, and functional and radiological parameters. The included studies with a minimal follow-up of at least 8 years showed good survival outcomes after surgery varying between 68% at 18 years’ and 86% at 30 years’ follow-up. Furthermore, the Chiari procedure may also be able to increase hip scores and restore radiological angles within normal ranges, with minimal occurrences of major complications.

Careful selection of patients is important for the success of any surgery. However, the outcomes between the included studies were difficult to compare, because of heterogeneous patient characteristics due to differences in inclusion (Tables 1 and 2), ranging from pain, and/or dysplasia with and without concurrent OA, to avascular necrosis of the femoral head and with a negative or positive preoperative CEA. Migaud et al. (17) recommend that the Chiari osteotomy should be done in patients with severe arthrosis and low CEA regardless of present subluxation or the loss of congruency. However, higher levels of arthrosis by itself are again a negative survival factor (16,19). Moreover, patients with deformities of the femoral head were reported to be more vulnerable to the progression of OA (19,21), as it can be associated with bone atrophy, poor repair, or the presence of acetabular labral tears (19). Yet again, the Chiari osteotomy is preferred over the peri-acetabular osteotomy (PAO) in hips with dysplasia where pelvic remodeling is restricted due to extreme dysplasia or aspheric femoral heads (5,9,23). This lack of consensus makes it difficult to appraise the Chiari osteotomy in relation to other procedures.

In the included studies, often a combination was made between the Chiari osteotomy and, e.g., a femoral osteotomy, making it difficult to ascribe the success of the survival time solely to the value of the Chiari osteotomy, and differences in the THA conversion endpoints amplify this effect. However, in 1 study by Ito et al. (24), 87% of all Chiari procedures were combined with a varus osteotomy, they did not find a significant difference between the group with or without femur oste-
otomy, and survival was also negatively affected by high age and the stage of OA (16,24).

Nonetheless, the Chiari procedure shows surprisingly high survival rates, in the four studies that reported Kaplan–Meier analysis with THA conversion as endpoint (Figure 2). Taking into account the high survival rates, complication rates, and radiological and functional improvements, this raises the question as to whether the Chiari osteotomy should be reconsidered in the palette of treatment options for developmental hip dysplasia.

The number of reported complications ranged from 0% to 28%, when excluding the number of patients with “thigh numbness” reported by Calvert et al. (15), which may be regarded as a direct and inevitable result of iatrogenic injury to the cutaneous nerves. It should be noted that after the Chiari osteotomy there is a potential decrease in pelvis diameter and if this (transverse mid-pelvic) diameter is < 9.5 cm the likelihood of a Caesarean section is increased (25). Moreover, despite it not being scored as a complication, some patients keep a persisting limp after the Chiari osteotomy. These factors should be explained to the patient when the Chiari procedure is considered as a treatment method. When the Chiari osteotomy is performed but needs to be converted to a THA it is good to mention that the salvage THA has comparable results to a primary THA (26).

The reviewed literature showed considerable limitations. First, all included articles were of level IV evidence with retrospective design and relatively small numbers, no control groups were present, and therefore it was difficult to make a comparison with a nonoperative, PAO, or shelf treatment. Moreover, evaluation time points in relation to the surgery or the number of patients per evaluation were often not reported. Second, the research population largely included females, but none of the included studies stratified for sex, which could have influenced results, and this could limit generalization to a male population, although the incidence of hip dysplasia is higher in women.

Nevertheless, in this era of advanced technology (27) and complex acetabular osteotomies (28,29), it may be useful to reassess the role of historical procedures such as the Chiari osteotomy, which may still have a role in selected clinical situations. Moreover, due to technological progression, additive manufacturing techniques are also being considered to treat hip dysplasia (28,30,31) and might help in planning and evaluating to increase the success of the Chiari osteotomy (29).

Conclusion
Chiari osteotomy has often yielded long-term hip preservation rates, can improve hip coverage, and hip functional parameters to near-normal values, and has a relatively low reported major complication rate. Moreover, when carefully selected for patients of young age, or minimal preoperative OA, patients may benefit from the Chiari osteotomy with satisfactory survival rates.

Supplementary data

**PUBMED Search**

Search terms
# 1 = Chiari*[Title/Abstract] OR Dome [Title/Abstract]
# 2 = (((((((arthroplast*[Title/Abstract]) OR procedure[Title/Abstract]) OR surgery[Title/Abstract]) OR operation[Title/Abstract]) OR acetabuloplast*[Title/Abstract]) OR hip[Title/Abstract]) OR osteotom*[Title/Abstract])
# 3 = #1 AND #2
# 4 = ((Hip[Title/Abstract]) OR Coxa[Title/Abstract]) OR Hips[Title/Abstract])
# 5 = dysplas*[Title/Abstract])
# 6 = # 3 AND # 4 AND # 5

**COCHRANE Search**

Search terms
# 1 = “Chiari*”:ti,ab,kw or “Dome”:ti,ab,kw
# 2 = (“arthroplast*”:ti,ab,kw OR “procedure”: ti,ab,kw OR “surgery”: ti,ab,kw OR “operation”: ti,ab,kw OR “acetabuloplast*”:ti,ab,kw OR “hip”: ti,ab,kw OR “osteotom*”:ti,ab,kw)
# 3 = #1 AND #2
# 4 = (“hip”: ti,ab,kw OR “coxa”: ti,ab,kw OR “hips”: ti,ab,kw)
# 5 = “dysplas*”:ti,ab,kw
# 6 = # 3 AND # 4 AND # 5

**EMBASE Search**

Search terms
# 1 = Chiari*:ab,ti OR Dome:ab,ti
# 2 = (arthroplast*:ab,ti OR procedure:ab,ti OR surgery:ab,ti OR operation:ab,ti OR acetabuloplast*:ab,ti OR hip:ab,ti OR osteotom*:ab,ti)
# 3 = #1 AND #2
# 4 = (hip:ab,ti OR coxa:ab,ti OR hips:ab,ti)
# 5 = dysplas*:ab,ti
# 6 = # 3 AND # 4 AND # 5