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Kyphectomy in myelomeningocele with a modified Dunn-McCarthy technique followed by an anterior inlayed strut graft

Received: 25 June 2003
Revised: 5 November 2003
Accepted: 28 November 2003
Published online: 9 January 2004
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Abstract Rigid congenital kyphosis in myelomeningocele is associated with an important morbidity with skin breakdown, recurrent infection, and decreased function. Kyphectomy is the classic treatment to restore spinal alignment; however, surgery is associated with an important morbidity and long-term correction is uncertain. The authors retrospectively reviewed 9 patients with a mean age of 8.8 years who underwent a two stage surgical procedure: first a posterior kyphectomy with a modified Dunn-McCarthy fixation consisting of lumbar pedicle screws and long S-shape rods buttressing the anterior sacrum. Then a second stage done several weeks later consisting of a thoraco-abdominal approach to the spine with an inlay strut graft classically from T10–S1. The mean follow-up was 34 months (range 1–5 years). The kyphosis was corrected from a mean of 110° of Cobb angle (range 70–130°) to 15°

after surgery (45–0°). There was no instrumentation failure, no loss of correction and no pseudarthrosis. Complications consisted of one intra-operative cardiac arrest fortunately reversible, a wound necrosis, one deep venous thrombosis and one late aseptic bursitis on the posterior hardware. Congenital kyphosis in myelomeningocele can be treated successfully with an initial posterior approach correction and instrumentation followed by an anterior approach allowing for anterior inlay impacted structural graft. The authors believe that this technique improves biomechanical and biological fusion mass anteriorly and will prevent late instrumentation failure and loss of correction.

Keywords Myelomeningocele · Kyphectomy · Posterior instrumentation · Anterior and posterior arthrodesis

Introduction

The incidence of congenital kyphosis in patients with myelomeningocele is 8–15% [5, 8, 9, 16]. The kyphotic deformity is usually progressive and increases patient's disability. Progression of deformity causes recurrent skin breakdown over the apex of the kyphosis, impaired sitting balance with the necessity of using the hands for support and collapse of the lower rib cage onto the anterior thighs, which may at term cause respiratory compromise.

Conservative treatment with spinal braces does not prevent progression of the deformity and exposes to skin

breakdown at the apex of the deformity [2, 11]. Many different techniques have been described for correction and stabilization since the first technique of kyphus resection described by Sharrard [16]. Classically, management of rigid congenital kyphosis in myelomeningocele is done by a kyphectomy followed by a posterior instrumented fusion; however, pseudarthrosis and loss of correction still occur after such technique [4, 9, 11, 12, 13, 14, 18], with a rate as high as 50% in some series [7].

The authors reported the results of a postero-anterior sequence designed by the senior author (V.A.). This technique is based first on the posterior correction associating a kyphectomy and a strong lumbopelvic fixation followed

Fig. 1 Planning the skin incisions. Depending on the previous skin quality, the previous flaps, and the meningocele extent, different incisions are chosen to avoid skin necrosis: straight, double incisions, or inverted-Y

by an anterior spinal fusion using an inlay strut graft. They believe in the role of the anterior graft to improve biomechanical, biological fusion mass, and long-term stability.

Materials and methods

Nine myelomeningocele patients with rigid lumbar or thoracolumbar congenital kyphosis were treated by the senior author (V.A.) with a posterior kyphectomy instrumented with a modified Dunn-McCarthy technique [13] followed by an anterior sequence with inlay anterior strut grafting.

Office and hospital charts, operating room report, clinic notes, X-rays, and patient photographs were retrospectively reviewed by an independent observer. Antero-posterior and lateral radiographs were reviewed before surgery, immediately after surgery and at the last follow-up in the sitting position to analyze the degree of correction. Measurements included the pre- and post-op angular kyphotic deformity and at the last follow-up.

There were 7 boys and 2 girls whose mean age at surgery was 8.8 years (5–13 years). All patients had no motor function below the thoracic level. All patients had undergone closure of the myelomeningocele sac at birth. Two of them had a recurrent deformity after failure of a previous limited posterior kyphectomy instrumented by Luque rods. One adolescent patient with a 90° thoracic lordosis above the congenital kyphosis underwent first an anterior thoracic release with costectomies followed by 2 weeks of halo traction before the kyphectomy was done. Indication for surgical correction was severe progressive spinal deformity resulting in decreasing function in all patients associated with recurrent pressure sores over the apex of the deformity in 5 patients.

Operative technique

All sites of skin breakdown were allowed to heal except for one where excision was done in the same procedure. Antibiotrophylaxy was given systematically intraoperatively with Cefazoline (Ancef) and gentamycine. All the patients received total parenteral nutrition after the first stage of surgery. Cell saver was used during the surgery.

The surgical management followed the sequence given below.

Exposure of the spine

A longitudinal skin incision is begun in the area of normal spinal anatomy and is carefully developed through the area of the previous sac closure. In case of poor skin condition due to multiple plastic flaps, skin adhesences or subdermal myelomeningocele, different incisions are used to preserve the skin vitality (straight, dual, and reverted Y incisions; Fig. 1). Skin flaps, as thick as possible, are then developed. Care is taken to avoid violating the subcutaneous dural sac. In the thoracic spine, the paraspinal musculature is elevated subperiostally with electrocautery. The dural sac is dissected and retracted laterally after identification and ligation of the segmental vessels and nerves. The dural sac was ligated in 2 patients.

Spinal instrumentation

We used a 5-mm titanium rod of the small-stature universal spine system (Fig. 2) in 8 children (Synthes, Paoli, Pa.) and in 1 child the Pediatric Isola rods system (Depuy-Acromed, Raynham, Mass.). The rods are contoured with in situ bending irons to fit the perfect anatomy of the upper sacrum ala and anterior aspect of S1, S2, and S3 as seen on the preoperative lateral sacrum X-rays. This in situ contouring is done prior to the surgery during the anesthesia preparation. We therefore do not recommend the use of standardized prebent rods that will not fit perfectly the anatomy of the upper sacrum.

On the proximal side of the rod we give purposely a 90° bend to have a constant knowledge of the intrapelvic orientation of the rod that we want to keep in a perfect sagittal plane (Fig. 2a).

The kyphectomy is planned as proximal as possible in order to have increased distal lumbar fixation. Pedicle screws are inserted below the planned area of kyphectomy. Because of the lack of muscle coverage and the specific orientation of the pedicles in dysraphic spine, the screws have to be oriented in an almost coronal fashion (Fig. 2b). Hooks, screws, or sublaminar titanium cables are inserted above the kyphectomy. In the children below 6 years, cables were only used in the thoracic area to preserve the trunk growth potential. A curved and smooth dissector is used to prepare for the insertion of the rod in front of the sacrum. The dissector is intro-

Fig. 2a–e Posterior sequence. **a** Precontouring of the rod to fit the anatomy of the upper sacrum. *Left*: the first bend has been given to the rod (arrow). *Middle*: the long S shape with the two bends has been given to the distal portion of the rod. Note the 90° proximal right angle curve to control rotation of the rod once inserted into the pelvis (arrow). *Right*: the rod inserted into the L5–S1 foramen buttressing the anterior sacrum. **b** Operative view of the insertion of the pre-countered long S-shaped rod over the sacrum ala. The tip of the rod goes into the L5–S1 foramen, over the sacral ala, and in front of the sacrum. In the front of the sacrum the rod is retroperitoneal underneath the bifurcation and in front of the sacrum. Note the lateral insertion and the coronal direction of the

pedicle screws around the kyphectomy (*thumbnail picture*). **c** The two rods have been inserted into the pelvis and locked into the distal pedicle screws. They will be cross-linked to prevent rotation and achieve distal stable foundation. **d** To avoid important bleeding, the spine has been exposed in an extraperiosteal fashion. The dural sac is usually not ligated but retracted laterally after the nerve roots are cut. Spinal resection is planned to include the more proximal compensatory lordotic deformity (*dotted lines*). **e** Once the kyphectomy is done, the correction is achieved by cantilevering the rods that were pointing to the ceiling on to the thoracic implants (cable wires for this patient)

duced through the L5–S1 foramen over the sacral ala and then anterior to the sacrum. Alternating small and smooth rocking movements of the dissector one frees the anterior aspect of the sacrum of the retroperitoneal contents. Great care is naturally taken to avoid injury to the great vessels located just anterior to the dissector. The path is therefore retroperitoneal behind the great vessels bifurca-

tion. The S-shaped rods are then introduced distally through the L5–S1 foramina. They buttress the anterior aspect of the sacrum to the S3 sacral piece. In the coronal plane we tried to give a slight medial curve towards the midline so they stay in front of the sacral body. The two rods are then inserted into the distal pedicle screws below the planned kyphectomy (Fig. 2a). They are then cross-linked

Fig. 3a,b Anterior procedure. **a** Exposition of the thoracolumbar spine. The head of the patient is on the left. The left side of the patient on the top. The lumbar spine has been exposed after the diaphragm has been detached. The anterior longitudinal ligament has been lifted off as a periosteal flap. The left common iliac artery and vein have been isolated on a non-latex vessel loop. The disc L5–S1 has been identified (tip of needle in L5–S1). Discectomies will then be performed, and a trough will be created in the vertebral bodies to allow the tibial strut graft to be keyed in between the S1 vertebral body and T10. **b** Preparation of the tibial bone graft (slide was taken prior to the dissection of the osteoperiosteal flap). The tibia is passed underneath the left common iliac artery and vein, and adjusted for its length and shape, so it will later be embedded into the lumbar trough and into the S1 and S2 vertebral body

together to make a solid distal foundation and prevent their rotation (Fig. 2c).

Kyphectomy

The dissection is continued laterally and anteriorly around the kyphosis in an extraperiosteal fashion so we can go around the spine into the sinus of the kyphosis. At the end of this stage, several fingers can be passed anterior to the kyphosis (Fig. 2d). The kyphectomy is done by removing one or two vertebral bodies (two on average) just above the kyphosis apex. Correction of the deformity is achieved by cantilevering the rods on to the thoracic implants (sub-laminar wires, hooks, or screws; Fig. 2e).

In case of associated scoliosis the principle of correction remains identical, as the spine column resection will allow the realignment of the spine with the help of the instrumentation.

The anterior sequence several weeks apart

The posterior sequence is followed by anterior spinal fusion several weeks after. A left thoraco-abdominal approach exposes the spine

from T10 to S1. After detaching the diaphragm the anterior lumbar spine is exposed completely and the segmental vessels ligated. The left common iliac artery and veins are dissected and isolated on a large vessel loop to allow free access to the lumbosacral junction (Fig. 3a). The left S shaped rod is usually felt but not seen as it is far laterally under the left iliac vein. A periosteal flap is elevated from the vertebra and the discectomies are performed (Fig. 3a). A trough is done in the vertebral bodies to embed the tibial graft. While the thoraco-lumbar approach is developed, the assistant will harvest a tibial strut graft from the medial cortex of one of the tibia. Its length is measured preoperatively and must span from T10 to the sacrum. Its width is usually limited to 7–10 mm because of the paralytic nature of bone. The tibial strut graft will then be impacted underneath the left common iliac vessels into the S1–S2 vertebral body (Fig. 3b). The strut graft is then inserted into the trough and keyed into the T10 vertebral body. The graft stability is checked and no fixation is required. A perfect shaping of the graft to the spine is allowed by the tibial graft flexibility (see Fig. 5a). Additional pieces of bone from the tenth rib are impacted in the disc spaces. In the case of only partial kyphosis correction having been achieved, the tibial strut bows string the kyphosis. Additional pieces of rib are therefore laid between the tibial strut and the spine (see Fig. 5a).

Results

The average preoperative lumbar kyphosis was decreased from 110° (130–70°) to 15° (45–0°) on average (Figs. 4, 5; Table 1). The mean follow-up was 34 months (range 12–60 months). All patients reported that their sitting posture had improved. No further skin breakdown was observed after surgery (Fig. 4).

The estimated blood loss was on average 21 for posterior surgery (range 1–41) and 11 for anterior surgery (range 0.5–21). The mean interval between posterior and anterior surgery was 4 months (1–6 months). There was no postoperative immobilization except for the two children aged 5 years who had worn an underarm plastic orthosis for 3 months. Early complications consisted of a cardiac arrest fortunately reversible during the surgery, and two CSF leaks that did not require reoperation and a syringopleural shunt injury. The cardiac arrest occurred during the kyphectomy and the patient required to be closed in emergency without the rods. The correction was been done 2 weeks later reinserting the rods without any specific complications. The anterior surgery was performed 6 months later when patient recovery status was maximized. One patient with a CSF leak had a partial wound necrosis that required a secondary excision, a dural tear suture and a closure by a latissimus dorsi flap. We had no infection. A deep venous thrombosis was observed. No fracture of the tibia where the bone graft was harvested happened. One patient had a posterior aseptic bursitis at 1 year after surgery that required debridement and partial hardware removal. No instrumentation failure, screw loosening or obvious pseudarthrosis were observed. No loss of correction was noted at the last follow-up visit. All fusions appeared solid as judged on the lateral lumbosacral spine X-rays where the tibial graft had been incorporated. (Fig. 5).

Fig. 4a–d Clinical example. **a** A 9-year-old boy with a 130° kyphosis, recurrent skin breakdown, difficulties sitting, and chest on

pelvis deformity. **b** Pre-operative X-rays. **c** Radiological correction at 1-year follow-up. **d** Clinical aspect after kyphectomy

Fig. 5a,b Clinical example. **a** A 10-year-old boy with a kyphosis of 75° and associated thoracic lordosis (*left*). Note the area of planned kyphectomy above the apex of the deformity (*white dots, left*). Note the preoperative planning of the tibial strut insertion (*in dotted lines, middle*) and the immediate post-kyphectomy lateral

film (*right*) with the tibial graft in place. Pieces of ribs have been inserted between the tibial strut and the spine. **b** No loss of correction at 2-year follow-up. Observe the coronal insertion of the lumbar pedicle screws. Osteo-integration of the anterior tibial graft

Table 1 Patient data. *TL* thoraco-lumbar, *CSF* cerebrospinal fluid

Patient no./gender	Age at operation (years)	Previous spine surgery	Kyphosis apex	Pre-op kyphosis	Post-op kyphosis	Last-visit kyphosis	Follow-up (months)	Complications
1/F	5	No	L3	130	20	20	32	Posterior bursitis at 1-year post-op
2/F	5	No	L3	100	30	30	30	–
3/M	10	No	L3	110	0	0	36	CSF leak+wound necrosis, dural tear repair+latissimus dorsi flap
4/M	9	No	L1	130	45	45	18	CSF leak resolved without treatment
5/M	13	Failure of previous segmental kyphectomy	L3	100	10	10	48	Thoracic anterior release, cardiac arrest reversible
6/M	11	No	L4	70	10	10	18	Syringo-pleural shunt injury
7/M	11	TL non-union after kyphectomy	L1	130	10	10	60	–
8/M	12	No	L4	100	0	0	18	–
9/M	12	Pressure sore excision in the same time	L3	130	20	20	12	CSF leak

Discussion

The surgical treatment of rigid congenital kyphosis in myelomeningocele is now well documented since the reports of Sharrard and Drennan in the 1970s [17]. As opposed to flexible kyphotic deformities that can be treated without bony excision, rigid congenital kyphosis requires kyphectomy.

A significant early morbidity is encountered with excision techniques, including death [4, 10, 14]. To decrease bleeding, we dissect the kyphosis in an extraperitoneal fashion detaching the posterior muscles and then the psoas muscles anteriorly. We found this to be less hemorrhagic than a subperiosteal dissection. The kyphectomy can be done without ligation of the dural sac if one sacrifices only the non-functional segmental lumbar nerves. It reduces the epidural vessels bleeding and possible hydrocephaly. Death from cardiac arrest attributed to intratechal pressure disorders were also reported after the spinal cord was divided and ligated [14, 20]. As advised by Mc Call [12] and Nolden et al. [15], lateral cord transposition allows enough space for the spinal resection in most of the cases (7 of 9 patients in our series). The dural sac can be likewise used as a “pad” to cover the spinal osteotomy. It provides vascularized tissue over the posterior aspect of the vertebrae and may enhance skin cicatrization. Alignment of the osteotomy site after kyphectomy may lead to significant bleeding making the situation worse as there is a decrease venous return due to the cantilevering reduction maneuvers. The osteotomy must therefore be closed quickly to

stop bleeding. All the implants and instrumentation must therefore be ready before the osteotomy.

Skin problems and infections are an important concern in all the series, up to 45% in Hull series [7]. Careful attention was given to the old scars, and we used zigzag, Y-inverted incisions, or double incisions at the beginning, to avoid wound necrosis. With experience, we tend to use a posterior median incision in most of our cases to avoid sharp corner and skin traction during surgery as recommended by Heydemann [4]. A low-profile instrumentation is recommended. The rods have to be placed laterally and the screws inserted in a coronal plane to be less prominent and to avoid a conflict with the soft tissues. This direction allows the maximum thread penetration in the vertebral body. We also recommend an additional total parenteral nutrition to promote wound healing and to prevent infection in the post-operative period.

Technique of osteotomy and the method of fixation are determinants for the amount of kyphosis angle correction. McCarthy et al. [13] reported on his technique using S-shaped rods over the sacral ala in the treatment of neuromuscular deformities; however, the S-shaped rods they use rest only over the top of the ala and do not buttress the anterior aspect of the sacrum anteriorly. By contrast, our contoured rods that match the anatomy of the whole sacrum allow a very powerful leverarm on the sacropelvis so that we can extend the sacroplevis at the time of the kyphosis correction. The best corrections are obtained by excising the proximal segment of the congenital kyphosis to include the more proximal compensatory lordotic deformity and fixed

distal thoracic lordosis [8, 9]. It leaves a long distal segment to insert screws in the lumbar vertebrae strengthening the lumbar-sacral fixation. Correction of the kyphosis angle has improved with the sacral fixation and the use of a rigid posterior fixation. The corrections reported have improved from half reduction of the kyphosis [14, 16] to mostly complete reduction with the introduction of these fixation methods [4, 6, 12, 19]. The additional lumbar pedicle screws and distal cross-linking improve the foundation of the construct to cantilever the sacropelvis into extension. Our instrumentation was judged solid enough that immediate sitting without external immobilization was possible in all our patients (except the 2 young children who had to wear a brace; Fig. 4). This has a definitive advantage when we know that immobilization is associated with an increased frequency of fractures in these children [11, 14].

As opposed to the literature, we have not observed any loss of correction over time. Maintenance of the post-operative correction and recurrence of the deformity are the main long-term concerns with all exclusive posterior techniques found in the literature [4, 7, 9, 11, 12, 14, 15, 20].

An average loss of correction of 20° is reported, especially in older children despite "solid" posterior fusion on X-rays [4, 8, 10, 12, 15, 17]. Losses of correction are also reported in association with the frequently observed pseudarthrosis. They require frequent repairs and gives instrumentation problems. We think that posterolateral grafts are not enough in these children and lack of ade-

quate fusion explains recurrence of the deformities. For these reasons, we use systematically an anterior fusion to augment our posterior fusion. The strut graft is an efficient method to resist against the gravity forces that could expose to the recurrence of the deformity if there is no thick anterior fusion (Fig. 5). This surgery can be performed in a relatively short time and without important morbidity [1, 3]. The anterior grafting is the main difference found in our series to explain the stability of the correction. One of the other advantages of a thick anterior fusion is that recurrence of the deformity is less likely to occur if removal of the posterior instrumentation becomes necessary due to a late infection of the instrumentation (as it frequently happens in these patients). We do not recommend carrying out the interbody fusion through the posterior approach, as this requires elevation and ligation of the dural sac, which can lead to increased bleeding and inadequate posterior discectomy. Moreover, the discectomy may fragilize the pedicle screw fixation and the fusion will not be as mechanically strong as an anterior strut, as our goal is to achieve as thick a fusion as possible.

Despite a decrease of the overall morbidity and an improvement of the operative techniques, the risks associated with such a procedure must reserve this surgery to specialized centers. These early results are in favor of strong lumbo-sacral fixation and a complementary anterior fusion to maintain the post-operative correction. Long-term follow-up is necessary to confirm these encouraging results.

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