Review

Reconsidering Diagnosis, Treatment, and Postoperative Care in Children with Cloacal Malformations

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ABSTRACT

Cloacal malformations are among the most complex types of anorectal malformation and are characterized by the urological, genital, and intestinal tracts opening through a single common channel in the perineum. Long-term outcome is affected by multiple factors, which include anatomical variants of the malformation itself, associated anomalies, and the surgical approach. Reconsidering these variables and their influence on "patient important" function might lead to strategies that are more outcome-driven than focused on the creation of normal anatomy. Key outcomes reflect function in each of the involved tracts and the follow-up needed should therefore not only include the classical fields of colorectal surgery and urology but also focus on items such as gynecology, sexuality, family-building, and quality of life as well as other psychological aspects. Involving patients and families in determining optimal treatment strategies and outcome measures could lead to improved outcomes for the individual patient. A strategy to support delivery of personalized care for patients with cloacal malformations by aiming to define the best functional outcomes achievable for any individual, then select the treatment pathway most likely deliver that, with the minimum morbidity and cost, would be attractive. Combining the current therapies with ongoing technological advances such as tissue expansion might be a way to achieve this.
Key Words: Cloacal malformation, Anorectal malformation, Congenital anomalies, Multidisciplinary treatment, Follow-up

Introduction

Cloacal malformations (CMs) are among the most complex types of anorectal malformations (ARMs) and are characterized by the urological, genital, and intestinal tracts opening through a single common channel in the perineum. Few centers therefore have a large experience because CMs are uncommon. The prevalence has been calculated to be 0.028 (95% confidence interval, 0.023-0.034) per 1000 total births (1.4 per 50,000) in 1 study of 4,251,241 births.[1] These prevalence figures are commensurate with other international data.[2-4]

CMs are associated with significant morbidity. Data exist to show that patients with the most severe types of ARMs, such as patients with CMs, experience worse outcomes across a range of measures.[5,6] Because a CM is a congenital malformation, the burden of disease might be carried for decades and affects the patient, her family, and the health economy. Associated VACTERL (vertebral-anorectal-cardiac-tracheo-esophageal-renal-limb) anomalies additionally worsen outcomes for individuals with ARMs. The number and severity of associated abnormalities seen in patients with CMs represent a significant additional factor.[5,7] The burden of care to patients, families, and the health care economy is an important consideration and infants with the most severe variants are likely to require more extensive reconstructive procedures. Some surgeries are done with reconstructive goals (for example, to allow menstruation or sexual activity) and a staged approach to reconstruction might be necessary. Other surgeries are done to improve symptoms such as urinary or fecal incontinence. For a range of reasons, therefore, multiple procedures might be required through the course of a lifetime.[8-10] Pain, inconvenience, and the cost of treatment are therefore important real-world considerations.[11]

If ARMs form a continuous spectrum, then the same might be true for CMs because there is wide variation in types and degrees of severity. Appreciation of the key issues likely to affect an individual's long-term outcome, including quality of life, would allow personalized care. This might limit morbidity, the burden of care, and resource use. Meaningful stratification of patients would also benefit research and innovation.

The aim of this review was to consider current approaches to the evaluation, treatment, and outcome mea-

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surement of women with CMs, and consider how further advances in personalized care might be achieved.

Diagnostics to Determine Anatomy; Recent Developments

The Krickenbeck classification was the first to differentiate types of ARM on the basis of true anatomical differences.[12] Further clarification for CMs was achieved by distinguishing short common channel types from long common channel types; those with a common channel more than 3 cm seen to have more challenging long-term outcomes.[13] However, the mechanism to measure common channel length varies. Centers might use radiological, surgical, or a mixture of approaches to estimate length of the common channel, and lengths measured might change with age.[10]

With an increasing focus on the evaluation of CMs, further factors have been identified that might influence outcome. Length and configuration of the urethra and bladder neck and its relation to the pelvic floor musculature are thought to be of importance.[14,15] Müllerian derivatives might have complex arrangements[16]; there might be partial or full uterovaginal duplication or there might be atresia, all with implications for sexual and reproductive health. The rectal pouch might end very low and enter the common channel very distally or it might stay very high and a long rectal fistulous tract might join the urogenital structures at a higher point.[10,17] These anatomical details are generally assessed preoperatively using transabdominal ultrasound, cysto-vaginoscopically, and by performing distal colostograms or cloacagrams. The latter 2 are invasive procedures with a small risk of complications, such as distal colonic perforation when performing a colostogram. Although the use of neonatal magnetic resonance imaging (MRI) was presented as a valid and useful diagnostic method to assess location of the colonic pouch and location and length of the rectal fistulous tract,[18] the role of neonatal MRI in evaluating patients with CMs might be contentious because MRI is not accurate for determining the length of the urethra and common channel.

Combined use of cystoscopy and MRI might be the optimal preoperative assessment for patients with CMs with a low risk of complications and low radiation dose. The use of 3D reconstruction after rotational fluoroscopy has proven useful in determining anatomy of structures that might overlap with conventional imaging techniques. Although the use of rotational imaging possibly increases the radiation dose for patients, it was reported that the rotational fluoroscopy only contributed 36% of the total radiation dose when 2-dimensional and 3D fluoroscopy were combined and total imaging time was decreased.[7,17] Nevertheless, modalities used to evaluate CMs should ideally be widely used across hospitals and available among treating centers.

The severity of associated anomalies in patients with CMs might influence other organ systems particularly those seen in the VACTERL association, leading to comorbidity. Two types of associated anomalies are of particular importance in determining potential for urinary and fecal continence in these patients. The presence of spinal anomalies (including lipomata, tethered cord, or variations of dysraphism) and sacral bone anomalies (including sacral dysgenesis or agenesis) are also associated with abnormalities of sacral nerve and peripheral development, both of which diminish the potential to achieve normal continence.[19,20]

Therapeutics; Current Surgical Strategies

Strict midline dissection (posterior sagittal approach) for the reconstruction of ARMs was proposed by Peña and Devries to allow a better anatomical view and reduce the risk of collateral nerve damage.[21] This remains a principle for patients with CMs.[22] The primary reconstructive goal has then been to create 3 separate perineal orifices. The principles of repair have changed considerably over the past several decades and this is important to review.

Posterior Sagittal Ano Recto Vagino Urethroplasty and Total Urogenital Mobilization

Before 1997 all patients underwent urogenital separation and PSARP (Posterior Sagittal Ano RectoPlasty) for the anal or posterior portion of the repair. The approach for the posterior portion of the repair has remained largely unchanged, although the use of laparoscopy has become a mainstream technique to dissect the rectum when a transabdominal approach is required. The significant changes have come about in the surgical approach to the anterior component. The separation of urinary, genital, and rectal components using a posterior sagittal approach (posterior sagittal ano recto vagino urethroplasty)[23] requires meticulous dissection. Particular care for the fragile “common” vaginal-urethral wall is required. After surgical separation, the vagina and urethra are mobilized to the appropriate location on the perineum and the perineal body is reconstructed.

The initial argument given for the introduction of the total urogenital mobilization (TUM)[22] was that it avoided the risks of urethrovaginal fistula through the en bloc mobilization of the urethra, bladder, and vagina together down to the perineum. The TUM procedure was presented as leading to better cosmetic results, avoidance of a difficult separation of urethra, and a shorter surgery time. Initially this technique was only proposed for use in patients with a short common channel (<3 cm), however over time it was proposed for patients with longer common channels, by performing the transabdominal TUM, for longer common channel patients.[13,24] Limitations to this technique exist particularly if there is a high confluence or short urethra.[15] Denervation or ischemia might occur in an already abnormal urethra and bladder neck. Bringing the bladder neck below the pelvic floor in case of a short urethra will impair urinary continence. Likewise, if the vagina(s) are small and short in length, mobilization might lead to ischemia with secondary stenosis or even complete loss of vagina, or a uterine cervix (or cervices) very close to the perineum. Technically there might be insufficient mobility in the pelvic organs to allow mobilization, and the pelvis might simply be too small.

Urinary incontinence might be further impaired when the bladder is mobilized from its attachments, especially if the dissection is circumferential and therefore disrupts innervation. Similarly bringing the bladder neck below the pelvic floor has the potential to lead to poor outcome.[11] More recently it has been proposed to select between these 2 techniques, urogenital separation and TUM more carefully by using common channel length and urethral length and making this selection before starting the procedure to prevent function loss as far as possible. TUM is widely used and almost always successful if the patient has a common channel of less than 3 cm and a urethra of greater than 1.5 cm. This anatomical configuration will allow mobilization without placing the bladder neck below the urogenital diaphragm as stated previously. In patients with longer common channels (>3 cm) or shorter urethras (<1.5 cm) urogenital separation, although technically challenging, will avoid overmobilization and loss of important functional structures, namely the urethra and bladder neck. Using these selection criteria, the maintenance of the urethra was shown to be possible in 87 of 91 cases (96%).[15] The posterior sagittal ano recto vagino urethroplasty and the TUM are still in widespread use for reconstructive surgery in patients with CMs and until newer techniques are developed, careful patient selection will hopefully lead to better functional outcomes for patients.

Vaginal Replacement

In some patients with CMs, the anatomy is such that vaginal reconstruction using a native vaginal structure or common channel remnants is not possible. For example, sufficient vagina to reach the perineum might not have developed or vaginal tissue might be lost by attempting to mobilize tenuous tissues. In these patients, vaginal replacement using nonvaginal tissues might be required.[13] Several different techniques have been described. The most commonly used tissues are small bowel and colon. Rectum may also be used but this needs to be considered carefully, particularly in patients with good potential for continence, because using rectum might have functional implications with regard to bowel control. In the presence of a large or markedly dilated rectum, the rectum might be divided, and an anterior vascularized portion may be used as neovagina and anastomosed to any native vaginal remnant. In many cases there is insufficient rectal tissue to create a neovagina as well as preserve enough rectum for fecal continence, and more proximal colon or small intestine should be used instead. In case of vaginal-uterine agenesis, a neovagina may be created for psycho-emotional well-being and/or sexual purposes.

Timing of vaginal replacement surgery, whether to be performed during the initial reconstruction or delay until adolescence has been debated. The benefits of creating a neovagina in adolescence or young adulthood, in a post pubertal patient, have to be weighed against the creation of such a graft in fully scarred tissues, which poses inherent challenges. For that reason, vaginal replacement during childhood is the most widely chosen option.

In the setting of vaginal-uterine duplication, “vaginal switch” has previously been used. The vaginal septum was removed and the proximal end of one of the vaginas is brought down to function as introitus. The procedure sacrifices vaginal capacity and 1 uterus and care must be taken to preserve both ovaries. This procedure is no longer in common use because of poor outcomes.[25] The use of colon and small bowel to replace the vagina has fallen out of favor during reconstruction in adolescents and adults because of poor functional outcome. In this older group, surgical procedures (using peritoneum, skin, or buccal mucosa) and when appropriate progressive vaginal dilation are successful to create or elongate the vagina, but these interventions have not been widely used in prepubertal children. Additional procedures have been attempted using amniotic membrane, urinary bladder, dura, and absorbable mesh to create neovaginas.[26-29] There is also interest in using in vitro grown tissue from buccal mucosa or decellularized vaginal matrix as a graft.[30-32] Anecdotally, fluid-filled obstructed vaginal moieties can generate useful tissue by a process of autoexpansion. There is research interest in the authors’ units in using tissue expansion as a potential strategy for vaginal replacement. Unfortunately, no single strategy covering all requirements to create a functional vagina with few side effects exists.

Surgical Procedures to Improve Functional Outcome

Over the years several surgical rescue procedures have been described to overcome some of the long-term sequelae in patients with CMs. Fecal incontinence has a significant effect on quality of life.[33] Medical management and or rectal washouts can be effective in some patients.[34] For these patients antegrade enemas might also be an option if washouts are likely to be needed long-term. Options to allow access to the colon are a cecostomy or a (Malone) antegrade continence enema, created using the appendix or other enteric conduit.[35,36]

Urinary drainage may be facilitated by catheterization. Providing a urinary meatus in the perineum has the advantage of being able to pass a catheter using that route. However, creation of a catheterizable channel using appendix or small bowel (Mitrofanoff principle) has proven to be successful.[37,38] If the storage volume of the bladder is inadequate, the capacity of the bladder may be increased by augmentation cystoplasty.[39] If the outlet is incompetent there are a number of surgical strategies to increase outlet resistance or to revise the perineal outlet.[40] This relies on catheterizable access to the urinary reservoir, and safe storage pressures must be demonstrated first to avoid threatening the upper urinary tracts. If attempted continent reconstruction of the urinary tract is not possible or not desired, the bladder neck may be closed and an incontinent cutaneous diversion (eg, an enteric conduit, using small bowel or colon) might be considered, with recognition of the attendant risks should the diversion obstruct.

Ongoing gynecologic assessment, education, support, medical intervention, and potentially surgeries optimize functional outcomes related to sexual and reproductive health. The onset of puberty brings many issues that re-

quire evaluation to the forefront.[16] Patients with CMs are at increased risk of menstrual tract obstruction, which can be associated with pain, adhesive disease, and endometriosis. Confirmation of Müllerian anatomy and clinical assessment for signs and symptoms of menstrual obstruction such as absence of expected menses, pelvic pain, urinary retention, or dysmenorrhea are important. If a menstrual obstruction is identified, conservative treatment with hormonal menstrual suppression while the level of obstruction is identified and preparation for the appropriate surgical correction is helpful. Menstrual obstruction might occur at any level of the gynecologic system and therefore a wide range of procedures might be indicated including introitoplasty, excision of a vaginal septum, vaginal replacement, or removal of uterine horns or remnants.

Because of the complex nature of human sexuality, a holistic approach with recognition of the importance of patient education, support, body acceptance, and other psychosocial factors is crucial for best functional outcomes. As developmentally appropriate, confidential conversations about sexuality, contraception, and family building are integral to care, with recognition that patient needs and desires might change over the course of her lifetime. An office perineal (and perhaps pelvic) exam on an awake patient facilitates discussion with a patient about her anatomy in a supportive manner, as well as assessment of the adequacy of the introitus for tampon use or penetrative sexual activity if desired. Some patients might require vaginal dilation, pelvic floor physical therapy, and/or introitoplasty to address painful or difficult vaginal penetration. Identification of a symptomatic vaginal septum or stenosis might require surgical correction. Shared medical decision-making should drive decisions about subsequent gynecologic procedures.

Family building might be a goal for patients with CMs and depending on their anatomy; some patients might require surgical intervention to enhance their success. Patients might require the creation of an anastomosis between the uterus and neovagina to allow for spontaneous conception, intrauterine insemination, or embryo transfer. If a patient requires oocyte retrieval for in vitro fertilization or in preparation for using a gestational surrogate, she might require vaginal or laparoscopic surgical interventions to accommodate a transvaginal approach to oocyte retrieval. For family building, a multidisciplinary evaluation by a dedicated gynecologist, pediatric surgeon, and urologist should determine anatomy, set expectations, and explain the diverse possibilities for treatment.

Prognostics; Using Outcome Data for Decision-making

Collection of long-term outcome data is necessary to inform improvements in the management of future patients, to facilitate discussion with the patient herself, and to set realistic “individualized” goals. Obtaining meaningful data might be difficult for a number of reasons; recording anatomical variation of the defect and of associated abnormalities might not always be precise, limiting accurate stratification of patients; symptoms, such as continence and constipation, are difficult to quantify and the choice of quality of life score varies between studies; patients might well live longer than the professional lifetime of the surgeon who took care of the patient in the newborn period; and because services are rarely designed to deliver “whole of life care,” patients might easily be lost to follow-up. The role of transitional care models in addressing some of these obstacles will be important.

Long-term outcome studies in patients with ARMs have generally focused on colorectal outcomes (ie, the ability to defecate spontaneously and to be fecally continent)[8,41] with less emphasis on urological outcomes.[42-44] For patients with CMs with the additional involvement of the gynecological tract as part of the condition, gynecological, obstetric, and sexual function outcomes must also be considered.[45-47] Assessing functional outcomes in an objective fashion is similarly difficult, and might even be more difficult because colorectal, urological, and sexual function also have an effect on each other. Reporting outcomes in relation to the effect on patients’ lives would provide much useful information (eg, psychosocial health and quality of life).[48,49] This should be extended to other forms of patient-reported outcome measures (PROMs) and patient-reported experience measures (PREMs) as part of “value-based health care,” preferably on a longitudinal basis and independent of the surgeon.[50]

Colorectal

Achieving gastrointestinal continuity is often a primary colorectal aim. Although initial creation of a colostomy allows drainage from the gastrointestinal tract for the period of reconstruction, the rectum is usually placed within the perineal muscle complex during definitive surgery.[13] This aims for achieving total fecal continence or at least socially acceptable bowel function often referred to as voluntary bowel movements (VBM). VBM are reported in 24%-60% of patients with CMs.[51] Having VBM is one part of adequate anorectal function, however fecal soiling can coexist with having VBM, and thus limit good functional outcome. Soiling is present in 14%-83% of patients with CMs. Furthermore, a large proportion of patients suffer from constipation and are offered laxative or bowel washout treatments (28%-88% of patients). Bowel washouts are also part of the treatment of socially unacceptable soiling despite good VBM. To date, no study has investigated colorectal function specifically in CM patients with respect to the quality of life, PROMs, and PREMs, although ARM patients (irrespective of type of ARM) who suffered from fecal soiling are reported to have significantly lower scores for psychosocial health and school performance.[33]

Urological

Urinary tract anomalies combined with sacral and spinal anomalies make urological symptoms common in patients with CMs. Nine percent to 41% of cloaca patients have been reported to suffer some degree of urinary incontinence, with 18%-27% having undergone urinary tract surgery.[51] Studies show that 11%-75% of cloaca patients have abnormal or deteriorating renal function. Some of these patients developed established renal failure and underwent kidney

transplantation.[52] Deaths because of chronic kidney disease are reported but the true incidence remains unknown. Causes of renal failure in these patients might be a combination of congenital renal anomalies (structural anomalies, dysplasia, or single kidney), the influence of anatomical anomalies and physiology (for example, storage pressures) of the lower urinary tracts, and a higher risk of recurrent urinary tract infections.[53] Lifelong monitoring of urological function and kidney function is therefore mandatory.

Gynecological and Sexual Function

Although colorectal and urological outcomes are the main focus during childhood, gynecological outcomes gain clinical relevance during puberty and have become of increasing interest in recent years. It has been noted that omitting a thorough assessment of genital anatomy might lead to the need for acute surgical interventions as a result of an obstructed menstrual flow in 15%-38% of patients with CMs; sometimes this led to hysterectomies.[47,51,54] Only 32%-62% of the small group of patients in whom gynecological function has been reported had normal menses. A significant proportion have primary amenorrhea typically due to the anatomical features of the malformation (ie, obstruction of menstrual flow) or removal of functional uterus/endometrial tissue during surgical procedures. Primary or secondary hormonal causes are very rare, because the gonads are typically unaffected.

Creating continuity of the genital tract in a newborn or infant has significant long-term morbidity. Up to 56% of these patients required a redo vaginoplasty as a result of several complications, such as vaginal stricture or residual vaginal septum.[55] With these numbers, a gynecological physical assessment (using general anesthesia if needed) is advisable in all adolescent cloaca patients to pre-empt the need for later intervention. Using a clear classification system for female genital tract congenital anomalies, such as the European Society of Human Reproduction and Embryology and the European Society for Gynaecological Endoscopy classification system, might be helpful to categorize anomalies and to guide clinical practice.[56]

Sexual outcome in cloaca patients is rarely reported but undoubtedly important. The reports in recent literature indicate that between 42% and 57% of women with cloaca are sexually active.[47] Problems during intercourse were only reported in 2 studies and were reported in up to 21% of the patients, comprising painful penetration and painful intercourse. The same recent reports also included reproductive function in cloaca patients, and there are cases of successful pregnancies.[57] A recent review article reported on all of the available obstetrical outcomes in the literature in patients with CMs.[58] There were no maternal mortalities and the most common complications were recurrent urinary tract infections and premature deliveries secondary to spontaneous preterm labor. Patients with CMs had varying modes of delivery including vaginal delivery, operative vaginal delivery, and cesarean section. There are currently no evidence-based recommendations regarding mode of delivery in patients with CMs. Multidisciplinary discussion and shared medical decision-making are critical and must include comparisons of the potential risks of vaginal delivery on the pelvic floor and continence with the risks of cesarean section with consideration of previous surgeries, urinary conduits, stomas, adhesive disease, and comorbidities. Expert opinion as cited in the review article favors cesarean section for patients with neovaginas and most patients with CMs. Currently it seems wise to recommend scheduled cesarean section to avoid risk of damage to the pelvic floor reconstruction or pelvic organs, and to safeguard urinary reconstructions. Care must be taken when performing a cesarean section in the presence of a urinary reconstruction or colostomy so as not to threaten its integrity. Patients might benefit from a multidisciplinary surgical team and avoidance of emergent cesarean section at the time of delivery because intraoperative complications are not uncommon.[59]

Psychological/Quality of Life

The psychological burden of being born with a CM is still unknown, although appearance of support groups is testimony to its importance. Programs also involving psychology do exist in some specialized centers, which emphasizes the importance of multidisciplinary and multiprofessional working.[60] To date, only 1 study has specifically reported on quality of life issues in CM patients.[33] This study revealed that although cloaca patients report a similar quality of life as female peers who have less complex ARMs and healthy peers, proxy reports by parents show lower scores on school performance compared with the reports by parents of the less complex patient group, and lower overall quality of life and psychosocial performance compared with the reports of parents of healthy peers. Psychosocial assessment and follow-up therefore appears to be of great importance in these patients.

Optimizing Treatment for Individual Patients

Involving Service Users

The focus of any medical treatment is increasingly on the basis of factors that patients themselves deem important. Partnerships with patient groups and formal incorporation of patient-public involvement in research underline this activity. Development of a sophisticated mechanism to record and include the view of a representative group of patients would enrich the care of future CM patients.[61,62]

Recognition of the best likely outcomes for any individual would be enormously useful for the patient, their family, and their clinical team, and constitutes personalized medicine.[63] For example, a combination of a severe cloacal abnormality, a spinal cord abnormality, a poor sacrum, and poor perineal and pelvic musculature would suggest a poor prognosis in terms of fecal incontinence. A child with these features might be entered into a bowel management program at an appropriate time rather than having to try a range of therapies that have the potential to carry their own morbidity with limited benefit. Decision-making to achieve such personalized care will be an aspiration of many centers and should be delivered in partnership with

families, and subsequently with patients themselves. This is not always easy to deliver in practice and consideration of the barriers in each center might be helpful.

Because CM is a heterogenous condition, identification of the likely long-term outcome for any individual patient is more challenging. Furthermore, the nature of congenital abnormalities is that symptoms change over the decades with puberty, perhaps childbirth, and senescence. Certainly, some features, such as sexual dysfunction or effect on employment, would only become apparent at certain ages. Furthermore, because it is a multisystem disorder, all systems have an effect on each other with respect to functional outcome as well as PROMs/PREMs. Mechanisms necessary to identify and collect data on key long-term outcomes require codesign with service users.

Involving Other Service Providers

As well as patient groups, defining the outcomes seen as important by a range of pediatric and adult clinicians who care for patients with CMs (eg, colorectal surgeons, gynecologists, obstetricians, urologists, nephrologists, transplant surgeons, primary care physicians, orthopedic surgeons, neurosurgeons, psychologists, cardiologists) might usefully highlight the problems that might be encountered at different ages, allowing some to be prevented or diagnosed early. Engagement with those charged with administration of the health care economy would allow metrics considered important to them to also be considered, which would enhance the ability to lobby on behalf of patients. A health economics perspective is increasingly important in many countries and is beginning to affect decision-making in North America.[50]

The nature of some of the symptoms either are embarrassing (and therefore likely to be associated with underreporting), or difficult to measure. A structured attempt to capture these would add rigor. Involvement of experts in the practice of outcome measurement, as well as service users would be valuable. Meaningful attempts to define and address barriers to the collection of necessary data would allow teams to begin to predict the likely range of outcomes for a girl newly diagnosed with cloaca.

The Role of Anatomy and Change with Age

The anatomy of the defect is likely to change with time, growth and development, the effect of hormonal status, or the effects of previous surgery. Knowing the best age to intervene is worthy of focus. The issue of consent in relation to the age at surgical correction has proven to be thorny in patient with disorders of sex development but this has been less contentious for CMs. A clear agreement on principles would make it likely that future discussion remains patient-centered.

The Role of Technology, Research, and Innovation

Technology has changed immensely over recent decades and is likely to continue to do so. Nevertheless, approaches such as robot-assisted procedures, tissue expanders to treat soft tissue defects, or even tissue engineering have been used less often in pediatric and neonatal practice compared with in older age groups. Resource needed to facilitate the research needed to develop such approaches is more difficult to obtain from grant-awarding bodies whose focus tends to be on high-volume conditions. For similar reasons, commercialization of novel techniques or therapies is also more difficult to achieve. The risk of embarking on a program that fails to robustly evaluate new treatments thoroughly is exemplified by recent events that have affected tissue engineering and must be avoided.[64]

In general, true personalized medicine would ensure treatments were selected to produce the optimal outcomes for an individual patient (taking into account her anatomy, physiology, and choice) with minimal intervention, morbidity, and minimal disruption for a patient, their family, or health economy. The judicious use of conservative management, technology, and radical surgery as appropriate might be needed to achieve this. There are patients with “milder” forms of CM in whom conservative management for some components of the defect is already recognized to be acceptable. Well considered innovative use of technology to address soft tissue defects in CMs has the potential to reduce the extent of surgical mobilization and therefore perhaps, comorbidity. For some patients formal reconstruction, performed by an experienced team, will be indicated.

Putting It Together: A Rationalized Approach

A strategy to support delivery of personalized care for patients with CMs with the aim to define the best functional outcomes achievable for any individual, then select the treatment pathway most likely deliver with the minimum morbidity and cost, would be attractive. Collaboration with patients, parents, and an appropriate range of service providers would allow codesign of mechanisms to evaluate new patients, deliver care, and measure results. Exploration of approaches that involve less dissection and less unlike-for-like tissue import are desirable. Development of surgical technologies, such as tissue expansion and perhaps tissue engineering, in combination with conventional surgical approaches might help achieve this.

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