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Orthopedic Techniques in the Management of the Residua of Paralytic Poliomyelitis

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Summary: In the developed world paralytic poliomyelitis is almost extinct. This is clearly not the case elsewhere While immunization has markedly decreased the incidence it has no effect on those who already have had the disease. These children are now mostly adults. This has a number of important orthopedic implications: 1) Adults do not heal as readily; 2) Postoperative regimens need to be extended; 3) Postoperative rehabilitation facilities will be in more demand; 3) Adults will have a more difficult time accommodating alterations in the mechanics that follows some operations. Well-intended surgery may not have the results expected; 4) What will be the worldwide impact of "Post-Polio syndrome (new functional loss that may occur many decades after the disease first occurred in childhood). By some estimates 40% of polio victims will suffer from Post-Polio syndrome as they reach their 50s and 60s. The decisions in the surgical treatment of polio are more difficult than the procedures themselves. Hurried decisions are frequently bad—if in doubt, proceed cautiously and in stages.Poliomyelitis—Prioritize treatment goals—Adult consequences of polio.

In the developed world paralytic poliomyelitis is almost extinct. This is clearly not the case elsewhere. Despite the availability of prophylactic vaccination, 960 cases were reported to World Health Organization (WHO) in 2004[1] (as of January 5, 2005 and his does not include the cases in the Western Hemisphere—see below). How many additional cases go unreported are not known, although in it has been estimated that only 1 in 10 child with the disease is reported.

While the incidence of poliomyelitis in the world is markedly decreased, it has not been eliminated. There has been considerable anticipation that the virus could be eliminated worldwide. The initial target date of the WHO was 2000. Recently, this has been extended to 2005. Now that 2005 has arrived, this date appears to be wishful thinking.

The incidence of new cases in the Western Hemisphere was said to be zero after 1994; however, recent outbreaks in the Dominican Republic and Haiti (2004) have proved this wrong. There is some suggestion that the reappearance in the Western world is because of mutation into the virulent form of the attenuated virus used during vaccination. Those who have been enthusiastic about the possibility of eliminating the virus have used the model of the small pox virus. However, there is reason to doubt that the model is not appropriate given the differences in the virus's effects.

Social factors play an important role in the effort to eliminate the polio virus. Recent outbreaks of the disease in Northern Nigeria resulted from rumors that the immunization would cause sterility among the immunized boys. Children who then developed the disease as a result of nonimmunization have spread the virus back into regions of West Africa where the disease had previously been declared polio free. The social problems of immunization were well illustrated in the article in the *New Yorker* magazine.[2]

ORTHOPAEDIC IMPLICATIONS OF THE CHANGING EPIDEMIOLOGY

While the incidence of new cases has been remarkably reduced, the availability of immunization has no effect

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on those who already have had the disease. These children are now mostly late teenagers and adults. The treatment of polio residua is now mostly an adult problem. This has a number of important orthopaedic implications.

- Adults do not heal as quickly or as readily.
- Postoperative regimens need to be extended
- Rehabilitation facilities postoperatively will be in more demand.
- Polio results in complex patterns of paralysis that require adjusting to. Because children are remarkably adaptable the alteration in the mechanics, which follows some operations, is quickly accommodated by children. Not so in adults. Well-intended surgery may not have the results expected.
- Another important issue for polio victims who are now adults—what will be the worldwide impact of "post-polio syndrome?" Here, the term post-polio syndrome refers to the recognition of new functional loss that may occur many decades after the disease first occurred in childhood. By some estimates 40% of polio victims will feel the scourge of post-polio syndrome as they reach their 50 seconds and 60 seconds.
- During the period when the incidence of new cases dramatically declined, medical facilities have improved in many regions were polio was endemic. Before, the huge numbers of cases often required modifications in surgical technique to accommodate the vast number of patients. This led to the advent of "Polio Camps" in India and elsewhere, where large numbers of children were operated on very commonly with per-cutaneous techniques, which were adequate, but not always optimal. As the medical facilities have become more prevailant, more standard techniques may be better selections.

IMPLICATIONS FOR SURGICAL TECHNIQUES

Few orthopaedic surgeons in the West have had much experience with poliomyelitis. Consequently, when a person with the residua of paralytic poliomyelitis presents for treatment, the orthopedist has difficulty knowing where to begin. Orthopaedic surgeons from developed countries who have taken positions in underdeveloped countries or those from the Third World who have taken their training in the West may find themselves equally without a solid background to approach these problems. Turning to the literature for help is overwhelming. Campbell's *Operative Orthopaedics* [3] alone has almost 40 pages related to the surgery of poliomyelitis and past editions (which are probably more useful to those still needing to treat patients with polio) had three times more. One can readily become enmeshed in a tangle of detail.

Although there are well-established patterns of polio, each person is different because of different combinations of paralyzes. This poses a special challenge to treatment. One can see persons with a totally flail leg who are able to walk brace-free or one with upper limbs so weak that they cannot support his body weight who somehow manages to use crutches to walk. Conversely, one often sees those with less impairment who have failed to reach their potential.

ESTABLISHMENT OF PRIORITIES

General

When first seeing someone who has had poliomyelitis, it is all too easy to focus on a single deformity. One needs to establish an overall program. To do so, priorities need to be established.

Thorough assessment is the cornerstone of priority setting regardless of the age of the patient. The person's gait (if he is walker) with and without his apparatus (ie, crutches and braces), his sitting capabilities, passive and active range of motion, and manual muscle testing of the extremities and trunk are basic. For those physicians dealing with polio frequently, a specific patient evaluation form will be an asset. Limb length discrepancy and scoliosis should not be overlooked.

Good manual muscle testing skills need to be relearned. A muscle usually loses one full grade when transferred. Therefore to be functionally useful a grade of at least 4 is necessary. However, a grade 3 muscle, while unable to provider a useful function after transfer, may be effective in preventing deformity by better balancing forces about a foot or hand. The orthopedist needs to be able to distinguish these differences and cannot expect to rely on the physical therapist for recording an adequate manual muscle test.

The most difficult assessment is the social/cultural one. Patient information is very frequently gathered through the filtering process of an interpreter and analyzed with limited understanding of local needs, uses, and geography. As often as not, it is these social and cultural factors, which become paramount in the success or failure of treatment

Will This Person Ever Walk?

Many patients who first present have never walked. For an orthopaedic surgeon, there can be few things as satisfying as converting a teenager, who has spent all of his life crawling, into an upright walker after relatively simple surgery and bracing. However, before embarking

on multiple surgeries, the most important question to be asked is "Can this person ever be converted into a walker?" As obvious as this may seem, we have been consulted on many patients who had undergone multiple procedures to no avail because the basic ingredients for walking were not present.

A person with one normal lower limb can usually be made to walk (with or without braces and crutches) regardless of the severity of the affected extremity. Some impairment in the good side can also lead one to be confident of the person's ability to become a walker. Even severe involvement of both lower limbs allows for walking provided the upper extremities and trunk are uninvolved, or only minimally involved.

A person whose both lower extremities are flail and who has inadequate upper extremity strength and control, is unlikely to become a walker, especially if the trunk muscles are at all impaired. A useful rapid guide of a person's ability to use his upper extremities to assist weak lowers is to ask the patient to place his hands on the examining table and to push down and lift his buttocks off the surface. Inability to do so is a bad omen.

Motivation of the patient and obesity become the critical factors in the marginal cases.

Priorities

It is our belief that the priorities of management are, by and large, sequential:

1. To get the patient walking;
2. If the patient is a child, correct factors that will create deformity with growth;
3. To correct factors that will obviate or reduce a lifetime dependency on an external brace;
4. To correct upper extremity problems;
5. To treat scoliosis.

While the surgical techniques appropriate for use in children with polio differ in that a great deal can be done by percutaneous procedures, standard techniques should not be overlooked.

The First Priority: Get the Patient Walking

If the patient is a child, it is initially important to get the child walking in any fashion and not get bogged down by a vision of walking perfection. Although the child may ultimately be able to walk without braces after appropriate releases, transfers and osteotomies, one does not need to do all such surgery at the beginning. Get the child up on his feet with the minimal contracture correction necessary by the simplest of releases and the simplest of braces.

The contracture releases required at this stage are most often the hip flexors and abductors, the fascia lata distally and the heel cord. The extent and duration of the deformities will dictate the techniques chosen.

Children under 3 or 4 will often respond to stretching exercises alone. Those a few years older (ie, 3–7 years) may do well with serial casting, while those older yet will probably require surgical releases.

1. Correction of Hip Flexion and Abductionntractures

Hip flexion contractures may occur in isolation, but more commonly they are associated with contractures of the tensor fascia lata and the gluteus medius tendon. Inability to extend the hips makes walking and standing difficult when unilateral, and nearly impossible when bilateral. The abduction contracture adds to this by tilting the pelvis laterally. This lateral pelvic tilt puts the high hip at risk for subluxation and may cause a secondary scoliosis.

When a knee flexion contracture is present, along with a hip flexion contracture, the Thomas test should be carried out with the knees over the edge of the bed. Otherwise, the knee flexion may well make the hip flexion *seem* greater than it is. An abduction contracture may only be revealed when the hips are fully extended.

At the time of surgery, many hip flexion and abduction contractures are relieved by radical release of the ileo tibial band and intra-muscular septum at the knee. If this does not result, then one can progress to an Ober release around the hip.

When doing an Ober release in older children and adults, the temptation to use subcutaneous tenotomies is best avoided. The proximal contracture of the abductors requires releasing far posteriorly or residual flexion deformity may be a problem if released percutaneously. A short transverse incision inferior to the anterior superior iliac spine is most easily used. The lateral cutaneous nerve of the thigh is exposed and protected. The relatively avascular plane between the tensor fascia lata and the sartorius is identified. The fascia of the Sartorius (or its whole bulk if functionless) is released. The tensor fascia lata is isolated and divided at its musculo-tendinous junction with cautery. Release is carried posteriorly to the gluteus fascia and tendon if necessary, especially in older patients. Occasionally it is necessary to release the straight head of the rectus femoris, less frequently the psoas and very rarely the joint capsule. After release, a residual of 20° will usually correct by subsequent stretching exercises in children younger than 10 years.

Bilateral long-leg casts and a tie-bar are applied with the affected leg in neutral adduction and rotation. Postoperatively the patient lies prone for 2 hours three times a day for 6 weeks. Stretching of the femoral nerve may

occur, so should be looked for immediately postoperatively.

2. Correction of Knee Flexion Contractures

Correction of knee flexion contractures may be accomplished by a number of different techniques that will depend on the age of the patient and the availability of medical facilities.

Serial Casting

Knee flexion contractures can be improved by casting in younger children. Age, the degree of contracture, available facilities, and the distance the patient has to travel all modify the plan of treatment. The cast treatment can most expeditiously be carried out in the following manner: the cast is applied without sedation or anesthesia; a short-leg cast is first applied; when it is firm, it is extended to a long-leg cast after first overwrapping the upper end of the short leg cast with padding. Thus, only the upper end of the cast needs to be changed at each subsequent visit. One hand gently molds the supra condylar area anteriorly (*NOT* over the patella) while the other pulls the posterior aspect of the upper tibia anteriorly. The very proximal most part of the thigh should be closely molded. Minimal force is used. Force can produce pressure sores, micro-fractures and flattening of the femoral condyles and posterior subluxation of the Tibia. The above-knee section of the cast is easily changed at 2 or 3 week intervals. One can expect approximately 10° of correction per cast change.

Lateral Release at the Knee (Yount Procedure)

All posterior structures can be released through a distal lateral incision. The lateral aspect of the quadriceps fascia and intermuscular septum are excised for a distance of at least 2 cm. If the lateral Hamstring is functionless, it is divided. If it functions, then it is recessed, or when the patient has no hip extensor, transferred to the distal femur to work as a hip extender. At each stage of the surgical release the degree of knee extension is checked.

In children under 10 years, at about minus 20° of extension, the residual deformity at the end of the surgical release will be easily corrected by postoperative serial casting. However, where the knee is still flexed to more than 20° and especially in older children and adults, the *medial* hamstrings are approached through a separate medial incision. These muscles are divided if they are functionless, or if functional can be lengthened or recessed (as for the lateral hamstrings see above). It is desirable to leave one hamstring so the knee can be actively flexed for squatting, but in very severe deformities (90° or more) they may have to be released.

If the knee still does not straighten out to more than minus 75°, then releasing the Gastrocnemius heads may to be considered where there is a strong Soleus.

Posterior capsulotomy of the knee should be avoided where possible but may be needed in an older child or adult with persisting deformity and posterior tibial subluxation.

Surgical Release Followed by Skeletal Traction or Femoral Shortening

If after soft tissues have been released, the contracture is greater than 60° or the neurovascular bundle is as tight as a piano wire, the femur may be shortened and extended (see below) or postoperative skeletal traction may be used.

Skeletal traction can be highly effective, and is our preferred choice. However, this technique does tie up hospital bed space often in just those situations where beds are already scarce.

If traction is used (especially in a patient who is small) a distal femoral pin (directed proximally and posteriorly) may be needed to provide counter-traction in addition to the usual pin in the proximal tibia.

The tibial traction should be directed anteriorly as well as distally to minimize or correct the posterior subluxation of the tibia. If there is a great deal of lateral tibial rotation on the femur secondary to a tight fascia lata and biceps femoris, the tibial traction can also be adjusted to help correct this.

It is not necessary to correct the contracture fully by traction. Usually about 2 to 3 weeks of traction is ample. Once all but 40° have been achieved, the remainder can be gained by serial casting.

Alternatively, to postoperative use of traction, the femur may be shortened during surgery by an amount adequate to relax the neurovascular structures when the limb is fully extended. Usually 2 or 3 cm suffices, and the femur is fixed internally. Shortening is more satisfactorily carried out when the problem is bilateral and the child close to skeletal maturity.

When stretching out knee flexion contractures, hypertension must be watched for. If drugs cannot control the hypertension, the joints must be relaxed back into some flexion.

Following the releases, the child should be stood up and started on walking training using his casts as temporary supports, while awaiting the fabrication of his braces.

Distal Femoral Extension Osteotomy

If the patient is an adult, or a child near maturity, or the contracture is recurrent, a femoral extension osteotomy at the supracondylar level is preferred. The femur is approached laterally and a Yount release performed first. Where the persisting contracture is in excess of 40° it is safest to shorten the femur. If the contracture is less than 20° an osteotomy can be performed leaving the posterior cortex and periosteum intact. By holding the leg in full extension in the cast, internal fixation is not required. The patient can be allowed to bear full weight and the cast need only be worn for 6 weeks.

When doing the osteotomy, it is important to *avoid taking a slightly laterally based wedge* thereby putting the knee into valgus. This is a very easy error to make.

If the patient has no potential for actively extending the knee, 10° to 15° of hyperextension should be the goal.

Large degrees of extension at the osteotomy will usually result in moderate loss of knee flexion. This can be a significant disability in cultures where sitting is done on the floor, or full flexion is needed for praying. In addition, excessive residual extension may result in a progressive hyperextension deformity, which is very difficult to treat.

3. Bracing

Braces should be kept simple. Initially, if undecided whether to brace below the knee or above, error is better made on the side of more extensive bracing. While a floor reaction ankle-foot orthosis (ie, "Pre-Tibial AFO") in slight equinus might ultimately work to stabilize an absent quadriceps, a person who has never walked before may well become frustrated without the instant stability provided by a simple long leg brace (ie, knee-ankle-foot orthosis or KAFO). Such a person may have a great deal of difficulty learning to stand, let alone walk. This lack of initial demonstrable success from your efforts may result in the patient disappearing back to where he had been crawling about, with him convinced of the uselessness of modern medicine.

For the same reason, the use of a walker may be the wisest initial choice. Later, progress can be made to axillary and then forearm crutches.

Naturally, the materials used in braces will depend on the facilities available. The lightness of plastic has to be balanced against durability and the relative ease of working steel and leather against weight. A patient who comes to a Western hospital and is provided with a sophisticated brace still needs to return to his home country where repairs may be difficult. Usually a broken metal and leather brace is more readily repaired by local craftsmen than a fractured plastic brace.

Whatever the material, certain principles must be followed. A patient who is unable to maintain his knee in extension requires a long-leg brace with lockable knee hinges (in many cultures where living is done at ground level, rather than in chairs, knee joints are not needed for smaller children until they go to school where chair use has been adopted almost worldwide). If the foot is flail, then ankle motion in the brace should be limited to approximately 15° of plantar- and dorsi-flexion. If dorsiflexion is paralyzed, a planter flexion stop at zero should be provided. Dorsi-flexion spring assists seldom stand the abuse of even a few months of use by an active patient, and are unnecessarily expensive. Where the foot and ankle are in balance, a free ankle joint is satisfactory.

If the younger child cannot balance the trunk over the legs, a pelvic band and hip hinges may be added to the long-leg brace *initially*. When both hip extensors are paralyzed, a hip lock can be added. As the child improves, it is possible to abandon the pelvic band. Our experience has been that the need for long-run use of a pelvic band has been virtually zero. If the problems are below the knee, then a single metal-upright below-knee brace is satisfactory, as long as the subtalar joint is balanced.

Where the subtalar joint of the foot is unbalanced, a molded plastic ankle-foot orthosis with anterior trim lines cut well forward provides much better control. If facilities for plastic molded braces are not available, a brace with a lateral iron and the requisite T-strap is used (For a patient with hind-foot valgus, the T-strap is attached to the medial side of the heel of the shoe and buckled around the lateral upright. For varus, the reverse is used with the T-strap attached to the lateral side of the shoe and buckled around the medial upright.).

The Second Priority: In a Growing Child, Prevent Deformity

Once a child is walking confidently (or if he presents initially as a walker), he should be assessed to focus on those problems that commonly result in deformity as the child grows.

1. Foot

Equinus

If the subtalar joint is unstable, equinus may be masked by heel eversion and mid-foot valgus. Examination of ankle motion should be done by first planter flexing the ankle fully, and then moving the hind-foot into inversion. With the foot held in this position, the ankle is tested for any limitation in dorsi-flexion

In most children under the age of 10 years, equinus can be corrected by serial casts. For the reasons described above, the equinus must be corrected while holding the foot in inversion. If this is not done a false correction can occur through the subtalar and mid-tarsal joints.

In older children, equinus is most expeditiously managed by lengthening the tendoachilles. It is important to remember that some degree of equinus contracture may mechanically stabilize the knee by forcing the tibia back at floor strike and thus the knee into hyperextension, in the same manner as a floor reaction A.F.O. ("Pre-Tibial AFO").

Where the quadriceps is present at a strength of 3 or better, the tendoachilles may be safely lengthened. However, if the child holds his knee in extension during stance by means of ankle equinus, lengthening the tendoachilles may take away the child's ability to walk without a brace. The difficulty arises when the child locks the knee with a combination of ankle push-off muscles *and* hip extension of variable power. There is no easy answer to the difficulty of analyzing this problem except to weigh the strength of the existing muscles against the severity of equinus and if the decision is made to correct the equinus, one should proceed cautiously possibly starting with serial casts (even if a child is older than 10 years).

If the child is a brace wearer and there is an equinus contracture, the contracture can be corrected for comfortable brace wearing, remembering always that there is a surprising amount of functional improvement with time in almost any given child, so one should not burn a bridge that may be useful later on.

Equinus need not be overcorrected. The foot is better left in neutral plantar flexion to increase stride length.

Only rarely will a posterior ankle capsulotomy be needed, even after very long-standing severe contractures. If you find that there is residual equinus after surgically lengthening the tendoachilles, it can be corrected by serial casting.

Drop-Foot

A drop-foot may be corrected by a brace or by appropriate transfers. Tendon transfers can improve dorsiflexion if suitable muscles are available to prevent the knee from buckling. Tendon transfers, however, will not correct the commonly associated equinus, so the equinus contracture must be dealt with first. A transfer of the tibialis posterior is ideal but seldom present. The peronei are the next choice followed by a Jones transfer of the EHL to the metatarsal neck if there is a cocked up great toe, or transfer of all of the long toe extensors proximally. Tenodesis of the anterior tibialis tendon into the tibia can be effective but may well stretch out, depending on the strength of the opposing plantar flexors.

Foot Valgus

An everted heel and valgus at the mid-foot with active peronei and lateral long toe extensors is a deforming combination that is commonly seen. The Grice-Green Sub-Talar Arthrodesis is effective in stabilizing the heel. The peronei should be transferred to the heel if the knee is likely to give way because of quadriceps weakness and to the dorsum if the knee is not likely to buckle unless there is a calcaneus deformity. In children who walk brace-free, the procedure can be done once the child is about 6. In those who are brace wearers, it may be postponed until the child is a little older, and it is obvious that either the deformity is progressing or the brace wearing is uncomfortable.

Stabilization and transfer should not be delayed too long, as stabilization of the heel and transfer of the peronei may make a later triple arthrodesis unnecessary. In children below he age of 10 years, most foot deformities can be corrected by soft tissue release combined with sub-talar stabilization.

As the child approaches maturity, a triple arthrodesis may be needed. In doing a triple arthrodesis for a foot which corrects passively, one can simply cut away the cartilage surfaces of the joints, which is easier than cutting wedges and results in much less foot shortening.

There is enormous variation between individual patients so that one may correct severe valgus deformity in a 20-year-old by soft tissue procedures alone and fail to do so in a 13 year old. Clearly, the amount of bony deformity on the lateral X-ray and the degree of correctability clinically are useful guides. If in doubt, it is best to proceed sequentially with a soft tissue release and later triple arthrodesis.

Equino-Varus

In the younger child the deformity may be corrected by casts and stabilized by bracing or tibialis posterior transfer. If the deformity returns or correction fails, then a posterio-medial release combined with a sub-talar fusion may be necessary, *making sure that the resulting fusion is not in varus*. The tibialis posterior should be transferred at the time of such surgery.

Calcaneus

If no muscles are available for transfer, then tenodesis of the tendoachilles to the fibula with the foot in 5° to 10° of plantar flexion controls the heel. In the growing child, this may lead to a more normal development of the Os

calcis and distal fibula.[4] When done before the age of 11 years, equinus may develop but this can be managed by lengthening the tenodesis.

2. Knee

Back-Knee Deformity

Back-knee deformity in a growing child should be protected by bracing. It can be controlled by a long-leg brace, in hopes that the posterior structures of the knee will tighten with time. Because no knee lock is usually needed, the knee hinges may have to be set in a few degrees of hyperextension if the leg is flail. If there is sufficient quadriceps to maintain stability with the knee in a little flexion, correction may be hastened by fabricating the brace in 10° to 20° of flexion at the knee provided the child is a rigorous brace wearer. Soft tissue correction of back-knee deformity by triple tenodesis[5] requires a long postoperative course of bent knee bracing and then serial casting. Patient compliance is mandatory. We have not been impressed by the technique but have had only limited experience with it.

Where the recurvatum occurs solely in the tibia, then a tibial osteotomy will correct it.

3. Surgery For Comfortable Brace Wearing

If the child proves that he is always going to be a brace wearer, then procedures should be aimed at comfort. It is wise to remember that in most children a spontaneous improvement in function occurs with time. Some children whom one thinks should not be able to walk free of a brace do so. Allow the child himself to prove that he will always be a brace wearer.

Procedures for brace comfort can be: 1) Release of equinus; 2) Stabilization of the sub-talar joint so that the medial malleolus does not become abraded by the medial upright of the brace or the T-strap; 3) Derotation of an externally rotated tibia; and 4) intravenously. Tenodesis of the tendoachilles to the fibula in the presence of calcaneus without another transfer available to prevent a painful heel.

4. The Dangling Leg

Where a child has a flail leg and normal upper extremities and trunk and a normal contralateral leg, he may learn to get about remarkably well by using crutches and dangling the affected limb. Leaving the situation as it is has the virtue of economy of medical effort but may not be in the child's best interest. Often such a child can be fitted with an appropriate long-leg brace and shoe lifts and then learns to walk without crutches. This has the advantage of freeing up his hands for more useful functions, as well as stimulating better growth in length of the flail limb. The bones will become more robust and may result in fewer fractures. The change from crutches and a dangling limb to a brace usually requires a period of crutch use and as well as the brace. This will appear to the child and the parents as a step backward. This difficult transition may require clever persuasion.

5. Leg Length Discrepancies

The degree of leg shortening that is acceptable to a child and the parents may depend on the culture. In the Western world 2 cm is considered a reasonable upper limit, however a far greater leg length difference is usually tolerated elsewhere, especially if surgery is the alternative. It is not surprising to find children with 6 to 8 cm differences who are largely unconcerned and assume the associated limp to be inevitable and are not interested in treatment of the problem.

When evaluating which leg length discrepancies to treat, several factors need to be considered in addition to the shortness of the leg: 1) A limb which will always require a brace should be left at least 1 cm short to allow for the thickness of the brace under the sole of the foot for easier swing through. This is particularly so if the child is to wear a long leg brace and has weak lateral trunk muscles so that he is unable to hike his hip enough to allow for the braced leg to swing through, in which case, 2 cm or more shortening may be preferable. 2) An affected limb may be associated with a dysplastic hip. Leaving the leg short can provide added coverage. 3) Other surgery anticipated for in later years should be integrated in the planning. A triple arthrodesis may further shorten a foot, as may an ankle fusion. By contrast a bone graft for a Grice-Green Sub-Talar Arthrodesis, if taken from the proximal Tibia, may give growth stimulation in the tibia. During these later surgeries, one should consider techniques that increase length (eg, adding an iliac graft between tibia and talus at the time of an ankle fusion).

The choice of treatment for a leg length discrepancy is likely to be different in non-Western countries. Small shoe lifts are not usable where sandals or "bare feet" are the custom, and children would rather limp than bother with the encumbrance of a shoe. Conversely, very large cosmetically unattractive shoe lifts may be readily accepted in lieu of surgery. While an epiphyseodesis might be the obvious treatment for many leg length discrepancies in the view of the orthopaedic surgeon, parents may not see the logic of operating on a good limb however much simpler the procedure may be in comparison to lengthening the short leg.

Leg length discrepancies in polio do not necessarily

increase in a predictable fashion. A 3 cm discrepancy at age five may not increase. A limb left to dangle may increase in length once weight bearing has been started. For this reason, if lengthening is planned, it is best left until after skeletal maturity is achieved when the exact difference to be made up will be known.

In some cultures (such as Saudi Arabia and parts of India) children do not celebrate birthdays. Age becomes a guess. It is hard for Western physicians who are accustomed to having 3 and 4 year olds know not only their age but also their exact birthdays to find 10 and 12 year olds who aren't sure of their age by up to 3 years. The use of skeletal age estimates by X-ray therefore becomes vital.

Leg lengthening capability is spreading worldwide. The parental preference of operating on the affected limb (as different from the normal limb in epiphyseodesis) and the enticing challenge to the surgeon has been proving overwhelming. Although the bones are very thin, they can be lengthened. If there is a choice between lengthening the femur or the tibia, our preference is to choose the tibia if possible because the lengthening apparatus can be removed earlier and replaced with a long leg cast or KAFO that decreases the likelihood of post lengthening fracture.

6. Hip Instability

Although a great deal has been written about regaining hip joint stability after polio, we have found the need for such surgery to be uncommon. As in the treatment of the unstable hip in myelodysplasia, a dislocated hip may not be a significant impairment to function, but multiple surgical attempts to regain muscle balance resulting in hip stiffness can be the cause of great disability. Hip stiffness is much more of a problem in cultures where floor sitting is an important activity of daily living—the very cultures where polio is still rampant.

The Third Priority: Decrease Bracing

Once the person is walking with confidence, and anticipated deformities cared for, one may ask, "*Can the child be made brace-free or can the bracing be decreased*?"

This is a controversial issue. Surgeons are more likely to favor the idea of a child undergoing a simple operation to obviate the need for a lifetime of bracing. Those who are less sanguine about surgery (that may include the child, the parents or any of the other care givers) may preclude such a choice. In addition, where facilities are limited, the option may not be available. The economics in the local situation will determine which route is more cost-effective (ie, a single operation versus a lifetime of brace fabrication and repairs).

The most important antigravity muscles are the quadriceps, the hip extensors, and the Gastroc-Soleus group. A person with absent quadriceps can walk brace-free provided he has hip extensors, or ankle plantar flexors (or a block to ankle dorsi-flexion secondary to a brace or surgical fusion), or a combination of both. These muscles will allow him to maintain the knee in extension so that it becomes mechanically stabilized by the ligaments of the knee that prevent hyperextension. A knee flexion contracture will make the knee unable to support the body in single leg stance by preventing the center of gravity from coming anterior to the axis of the knee joint.

Consequently the first step is to correct a knee flexion contracture. Contractures *cannot* be corrected by tendon transfers nor by bracing. In a child under the age of 2, contractures can usually be stretched out gradually by physical therapy. Older children respond to serial casting, while teenagers will usually require surgery. Any contracture will be improved by casting, but age, degree of contracture; available facilities and the distance the patient has to travel all modify the plan of treatment (see above).

A knee flexion contracture may exist in isolation, but is usually accompanied by contractures about the hip joint. A hip flexion contracture will make it impossible for the child to extend his knee without excessive lumbar lordosis. A contracted tensor fascia lata flexes the knee and twists the tibia into external rotation and valgus.

If the knee cannot be prevented from buckling in single leg stance (because of quadriceps weakness), then operations can be chosen that will achieve this. This will depend on the muscles available. Most commonly, an attempt is made to improve push-off by stabilizing the hindfoot and transferring the peronei and/or the long toe flexors posteriorly into the Os calcis. If the tibialis anterior is present, and the Peronei are to be transferred posteriorly to the Os calcis, the peroneus longus must be left alone if possible or tenodesed to the distal stump of the peroneus brevis, otherwise a dorsal bunion can occur.

A strong hamstring can be transferred anteriorly for knee extension. Transfers of the hamstrings into the patella have not proved popular in most societies where polio is still a problem because of the loss of the ability to flex the knee for floor sitting, squatting at toilet and praying.

In the patient near skeletal maturity, knee extension stability may often be easily obtained by a supracondylar extension osteotomy. This is most effective in a patient who can walk brace-free while using a hand to push the

thigh posteriorly to keep the knee in extension (ie, "a hand thrust gait").

In the absence of ankle planter flexion muscles, a patient may gain sufficient knee stability to discard a KAFO by an ankle fusion in slight equinus. If you are unsure of the outcome of such surgery, the child can be tested by fabricating a below the knee brace which fixes the ankle in equinus. The degree of equinus can be adjusted to find an optimal position. A short-leg cast can be used instead of a brace but the weight of the cast, and the uneven sole may make this a less reliable test. In a child who is skeletally immature and felt to be too young for an ankle fusion, the same effect can be gained by a tenodesis of the tendoachilles to the fibula.[6] However, this will only be expected to work if the subtalar joint is surgically stabilized either by a sub-talar arthrodesis in younger patients or a triple arthrodesis in older patients.

The Fourth Priority: Treat The Upper Extremity

Once a person is walking or it has been decided that he is doomed to be a sitter, attention may be turned to the upper limb. Clearly the function of the whole limb must be assessed. Classically, the upper limb is viewed as a mechanism to place the hand in space where it is needed to perform necessary functions. However, this thinking ignores the person's use of the upper extremities to support the body weight with crutches, or to shift trunk weight by leaning on the arm rest of a wheelchair, or even the ability of a patient to grasp objects between the humerus and the chest wall.

Stabilizing a flail shoulder frequently provides a significant improvement in the function of the elbow and the hand. Presumably this is because of the provision of a fixed point against which the muscles activating more distal segments can work. For this reason we prefer to consider the shoulder first.

1. Shoulder

A flail shoulder is a common abnormality in polio. On theoretical grounds, the restoration of function by tendon transfer is clearly more desirable than by fusion and the work of Saha[7] merits careful consideration. In practical terms, however, the most frequent solution for a flail shoulder is fusion. With the levator scapuli, the serratus anterior, and the medial scapular muscles present, a shoulder fusion can be very beneficial. To gain significant arm elevation after a shoulder fusion a strong serratus anterior is the most important factor required to rotate the scapula.

Our experience has concurred with that of Makin,[8] in that the shoulder should be fused early (between the ages of 6–8). The proximal humeral physis should be protected since it provides 80% of the growth of the humerus. This is best done by a cruciate incision in the articular cartilage, then peeling the cartilage away from the underlying bone (like peeling the skin off an orange). Fixation is by threaded pins removed at 6 to 12 weeks. The chance of injury to the proximal humeral physis is minimal with this technique. In older patients the A-O technique of plate fixation has proved to be excellent.

The position of fusion has been the source of considerable debate. Earlier experience with the fusion of shoulders in children demonstrated a gradual loss of abduction over the years after fusion prompting surgeons to recommend that the shoulder in children with polio be fused in +60° of abduction. This was a particular problem when fusion was done without internal fixation for fear of damaging the proximal humeral physis. With the advent of the use of internal fixation, this has not been a problem so the usually advocated postoperative position is preferred.

It is strongly advised to decide whether a Steindler flexorplasty will be necessary *before* the decision for shoulder fusion is made. Attempting a Steindler procedure with absence of shoulder external rotation after a shoulder fusion, make the Steindler operation markedly more difficult.

2. Elbow

The function of a normal hand is grossly limited if active elbow flexion is absent. Elbow flexion may be restored in a number of ways: by transferring the origin of the wrist flexors or extensors (or both) proximally (ie, Steindler Flexor Plasty); by transfer of the pectoralis major; or transfer of the triceps forward to the biceps; or by transfer of the latisimus dorsi on its neurovascular pedicle.

Care must be taken not to lose an important function with such transfers. Some elbow flexion contracture will result from any of these operations. Moving the triceps forward to act as an elbow flexor may cause a loss of elbow stability in extension, thereby losing the ability to use crutches. Inability to extend the elbow may eliminate the backward reach needed to get to the starting position for wheelchair propulsion. Lack of active elbow extension may result in an inability to stabilize paper on a desk with one hand to write with the other. Furthermore, after anterior transfer of the triceps, elevation of the arm will be less functional if the forearm flops into flexion.

3. Forearm

A pronation contracture of the forearm may cause a functional loss not seen in the West—the person cannot

feed himself if he is a member of a culture that eats food with their fingers rather than utensils. In a number of parts of the world, the main eating utensil is the hand, and the hand must be supinated to get food into the mouth. A pronation contracture is best treated by total release of the interosseous membrane (approached volarly) holding the corrected position in a cast for 6 to 8 weeks and maintaining the correction by physical therapy afterward.

A supination contracture will allow the child to feed himself, but the absence of pronation means that usual hand work is impossible especially with the advent of the importance of keyboard use. Release of the contracture (approached dorsally) and re-routing of the biceps tendon to provide pronation (Zancolli procedure) can improve function, but the balance between a working hand and a feeding hand must be assessed. The Zancolli procedure should only be used where there is an additional supinator other than the biceps or else a pronation contracture can result.

In the older child, or an adult, it is sometimes necessary to carry out derotation osteotomies of the forearm to correct these deformities.

4. Hand

Lack of opposition may be dealt with by any of the classic techniques taking care to correct any abduction contracture of the thumb, which may coexist. In crutch walkers, the procedure should be delayed until the patient is able to cooperate, as there is a real concern that the transfer will stretch out. The patient need to understand that crutches cannot be used for at least 6 weeks and then the transfer needs to be protected for a further 3 months by a splint. Even afterward, the transfer can stretch out with crutch use. Serious consideration should be given to maintaining opposition with an iliac strut graft between the first and second metacarpals rather than with tendon transfers. The same concern should be exercised in patients who are obligate wheelchair users where the thumb may be used to rotate the wheel and can stretch out a transfer. Again, the better choice is that of a bone bridge between the first and second metacarpals.

Metacarpal-phalangeal and inter-phalangeal joint contractures may be stretched out with a combination of physical therapy and dynamic bracing, but frequently, release of the metacarpal-phalangeal joints needs to be carried out. Restoration of function in the supple hand is carried out along the principles firmly laid down in a number of hand surgery texts.

The Fifth Priority: Treat the Scoliosis

1. General

Scoliosis in many children with polio is focused at the lumbar region. Respiratory difficulty is less a long run concern than the effect of the spinal curve on functioning—walking and sitting.

As a general rule, there is little role for bracing in the treatment of children with scoliosis because of polio. Bracing a lumbar curve often makes walking impossible. Bracing a thoracic curve when the child has no muscles to withdraw from the pressures of a brace may lead to sores and further restrict respiration.

When a curve is noted, baseline antero-posterior and lateral X-ray should be taken with the patient sitting unsupported, either by his hands or an attendant (who think he is being helpful). Standing films can give important information concerning the role played by leg length discrepancy and pelvic tilt, but the variations in lower extremity brace wear and the degree of spine stretching provided by using crutches to stand makes standing films more suspects. Sitting films will usually be more consistent.

One should look for asymmetric hip abduction contractures. Surgical release of these may be all that is needed to allow the spine to straighten.

Scoliotic spines in children resulting from polio tend to be much more flexible than those seen in idiopathic scoliosis. This is particularly evident in children under about 14. Thereafter, the curves tend to become rigid quickly. Consequently, an increasing curve seen on upright films (which would ordinarily signal the need for surgery) can often be ignored temporarily in younger children. The indication for surgery becomes not progression alone, but when stiffening becomes evident in a progressive curve. Thus, intermittent bending films can be useful. For an example, an 8-year-old child with a curve which has progressed to 40° but which bends down to 20° may be seen to progress to 60° or even 80° over the next 3 or 4 years, while the bending film still shows the curve reducing to 20°. Surgery at age 12 years will result in a curve no worse than if it had been done at age 8 years, yet the child will be taller and you will have avoided a spine fusion that might necessitate the use of extendable internal fixation with its concomitant complications.

Stabilizing the lumbar spine may decrease (or totally prevent) the patient's ability to walk, whether the sacrum is included. A supple lumbar spine may be necessary not only for forward movement but also lateral "balance." This may be insignificant in a crutch-free and brace-free child, but it may be catastrophic in a marginal household

walker. Children and parents not warned of this potential difficulty with walking will be justifiably upset if their child stops walking after a spine fusion.

Loss of lumbar lordosis following spine surgery can be a major problem if the hip extensors are weak because there will be no way for the child to lean back and get the mass of their trunk posterior to the hip joints. Every care must be taken to avoid this.

2. The Child Under 10

There is less need to be aggressive in the young child with scoliosis resulting from polio because progression is slower and flexibility usually maintained into the early teens. In addition, the curves can begin so early that embarking on spinal bracing early on requires so many years of brace wear, which can be a particular problem in hot climates. Because surgery is so commonly the final treatment, a curve that remains flexible may end up with almost the same degree of curve if fused at age 12 instead of at age 8 (see above).

If the child is only able to sit (rather than to walk) and needs to use his hands to support his trunk or the curve is greater than 60°, posterior spine fusion should be offered. However, it is important to remember that children with paralytic scoliosis often use their curve, particularly the kyphotic and lordotic elements to balance their trunks. The great majority of children in non-Western countries sit on the carpet. Straightening the spine means that they are inclined to fall over like a spent top. Fortunately, this is usually only temporary. Sitting in a chair corrects the problem but it may not be popular. The parents should be warned accordingly.

3. Children Between 10 and Puberty

Clearly, sitters can be fused early as the trunk length becomes less important. The temporary difficulty with sitting on a carpet needs to be stressed.

The type of instrumentation and fusion depends on the curve. A lumbar curve is the commonest and corrects well with anterior instrumentation reinforced with a secondary posterior fusion. While some types of anterior fixation can exacerbate a lumbar kyphosis, usually the kyphosis is more apparent than real and caused by marked rotation of the spine. If care is taken during surgery to derotate as much as possible and the fixation screws placed well posteriorly, there are few times when kyphosis is significantly increased.

4. Timing of Scoliosis Surgery in Relation to Lower Extremity Surgery

If an older nonwalking child is first seen with a severe scoliosis, it is our practice to fuse the spine first, before doing the lower limb releases required for standing. This is based on the observation that getting such an older child up and walking after lower limb releases may take many months, during which time the curve is worsening. Then when the spinal surgery is finally undertaken, the "learning-to-walk" process has to be started all over again after the spinal surgery.

SUMMARY

The decisions in the surgical treatment of polio are more difficult than the procedures themselves. Although there are well-established patterns of the disease, each patient is different and one can never say never. Hurried decisions are frequently bad; if in doubt, proceed cautiously and in stages.

We have suggested a sequential philosophy of management, but obviously, with experience, various stages may be carried out at the same time.

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