Working in Resource-Challenged Environments

14

Scott C. Nelson and Hugh G. Watts

Introduction

Due to the considerable responsibility that we as pediatric limb deformity surgeons have to our patients and their families, we should never compromise our surgical principles based on the circumstances or location in which we perform operations. The techniques outlined in the chapters of this book have applicability to every part of the world and thus will not be rewritten in this chapter. The limited resource environment presents some unique challenges which often create the need for improvisation and innovation, but this must not be allowed to compromise our results. Indications and surgical techniques may vary based on the type and severity of limb deformities being treated, but surgical principles should remain the same independent of geographic location.

Never before in history have both patient needs and available treatment options been so great. As globalization, communication, and technology increase so do our opportunities to develop and maintain international relationships with other health care providers. This presents possibilities for education and enhances patient care. The potential reasons for the high prevalence of congenital, post traumatic and post infectious limb deformities in resource limited locations includes the following: Lack of environmental regulation (teratogenic pollutants in the air, soil and water), lack of education, urbanization, transportation-related injuries, natural disaster, lack of prenatal care, consanguineous relationships, and limited access to health care. The world population is growing fastest in resource limited environments. The population on this planet is now more than seven billion persons—which is double what it was in the 1970s and quadruple what it was in the 1930s. Income disparity between wealthy and poor continues to increase as well (Table 14.1) [1, 2].

The healthcare resource disparity is even higher at more than 88–1 [3]. Meaning that in places like North America we spend more than 88 times the amount of resources on our own healthcare than what is available for many people in the world. In the USA and in other developed countries, the primary concern is toward the medical care of the aging population. But as Fig. 14.1 [4] shows, children make up a much larger portion of the population in Africa than in the USA. These two population samples exemplify the general trend in population proportion between developed and developing countries.

As pediatric limb deformity surgeons, there is an increasing urgency to engage in service where needs are increasing and resources are relatively decreasing (Box 14.1).

International relationships and mutual understanding between health care providers around the world are necessary to build sustainable programs that will best be able to serve the needs of children with limb deformities. This chapter is written both for surgeons wishing to provide humanitarian service in foreign countries as well as practicing surgeons who are citizens of countries with limited resources.

Box 14.1. Factors affecting prevalence of limb deformities in developing countries

- Lack of environmental regulation (teratogenic pollutants)
- Lack of education
- Urbanization
- Transportation-related injuries
- Natural disaster
- Lack of prenatal care
- Consanguineous relationships
- Limited access to health care

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International Collaboration

Volunteering and Hosting

National and international collaboration between surgeons can be a rewarding experience, both for the host and visiting surgeons and in the end, patient care is improved. Operating together with colleagues and other surgeons is a unique benefit of doing humanitarian work. Every opportunity to share knowledge and techniques with others should be sought, as it provides an opportunity for learning and expanding our ideas.

Good communication is essential to developing a working relationship between surgeons. This starts long before any planned time together and continues on long afterward. In the era of electronic communication it is now easy to do remote preoperative planning, and provide consultation in the follow-up period. Personal preparation as well as preparation of material and supply needs can be optimized by detailed communication.

Table 14.1 Relative wealth ratio between nations in the upper and lower percentiles of economic prosperity showing a severely progressive disparity between the richest and poorest countries in the world

Year	Wealth disparity
1820	4:1
1913	11:1
1950	35:1
2002	75:1

Commit to a Program

As limb deformity surgeons, we will be much more effective if we make a long-term commitment to a program in a resource limited environment rather than making first time visits to a wide variety of different locations. With repeat visits to a specific location expectations are established, relationships exist, communication is simplified and work can be done more effectively. Also, the value of long-term follow-up should be emphasized, both for the patient and for the surgeon. The quest for exploration and adventure is always intriguing and may be appropriate in certain situations. However, this should not be the motivating factor as such notions may dilute the quality and quantity of patient care.

Common Mistakes Made by Volunteers

1. Assume that you are going to teach someone your operative techniques. It is important to go with a humble attitude to first learn and then teach. Often times it is surprising how this attitude benefits everyone.

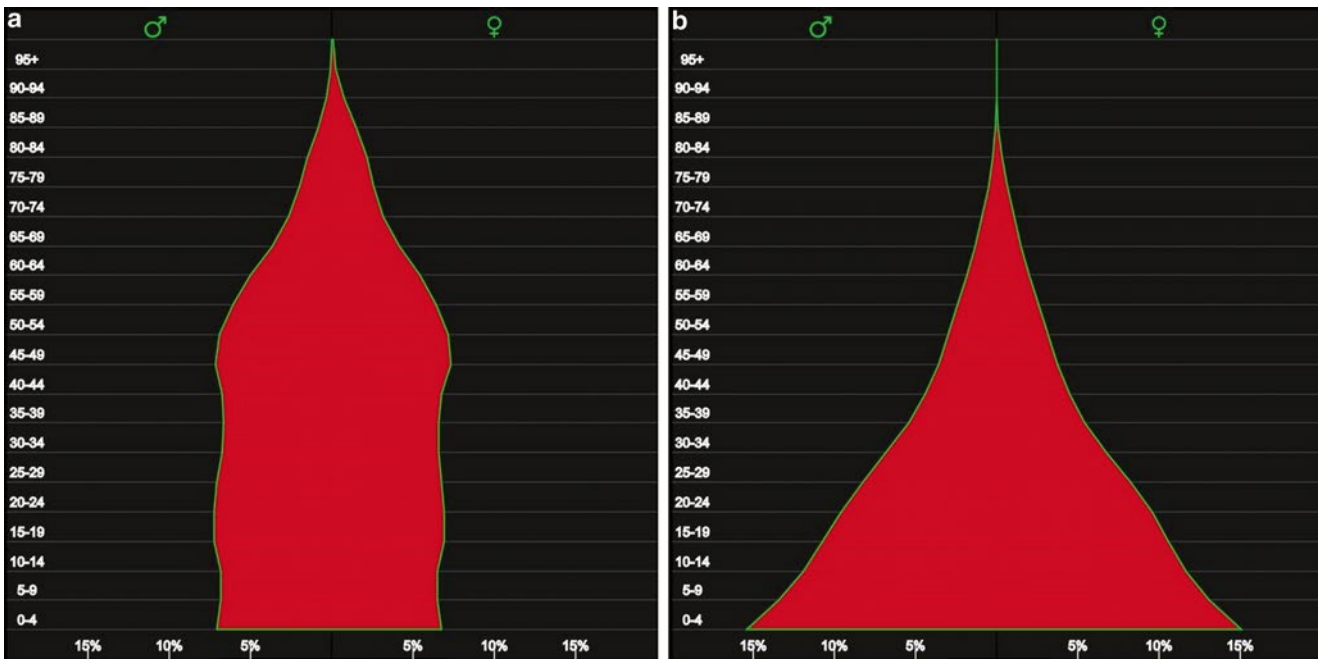


Fig. 14.1 US and African population pyramids. Population pyramids showing the distribution of the population by age in the USA (**a**) and Africa (**b**). 2010 statistics. http://www.worldlifeexpectancy.com/world-population-pyramid

2. Operate late every night and get as many cases done as possible. Situations vary and this may not be a mistake in all situations. However, relationships should be ultimately prioritized over pure production. Consideration must be given to local staff that often repeatedly host visitors and realize that your relationship with them is what will benefit everyone in the long term. As much as it pains the volunteer surgeon to leave behind a child with a deformity that could be corrected, it is sometimes best deferred to a more favorable time for the team and local staff.
3. Use materials and supplies as if you own the place. Opening up multiple packs of sutures, extra gloves, and other materials that may not be essential to the operation is wasteful and may be offensive to the local staff. Many of these items that we take for granted in our own countries are in short supply and are used very sparingly. Even if they are materials brought by yourself, it is best to respect the use of these with the local standard of discrimination since these items can be saved and used for future cases.
4. Make your gifts of materials and supplies the center of attention. Bringing equipment and gifts of supplies is really an obligation to have the privilege of operating in resource depleted hospitals. It must be remembered that volunteers coming to do charity work can be a financial burden on the hosting institution. Patient volume is often increased as are overhead costs for the hospital. It is wonderful if the hosting institution can afford to provide transportation, food and lodging, but in many situations they simply do not have the resources to do this and the mature volunteer should realize that it is often necessary to help with these expenses.

Common Mistakes Made by Hosts

1. Not being responsive to pre- and post-trip communications. Even in the era of modern communication our lives are busy and sometimes important emails and phone messages go unanswered.
2. Not having patients prepared and available for surgery. Hosts must understand that a visiting surgical team often times sacrifices thousands of dollars of lost income to come and do charity work. It is disrespectful if controllable factors have not been appropriately managed to make the most of the trip.
3. Planning operations that are not appropriate for the skills of the volunteers. This is avoided by adequate pre-trip communication and/or long-term relationships. In any case it is essential to know the capabilities of the visiting group.
4. Appropriate equipment exists but it is not available or missing. It is important to be organized and if equipment and materials exist then there is no excuse to not know where they are at the moment they are needed. Many times stock is lacking and this can be communicated ahead of time to the visiting teams who often have access to the needed items at their home institution. Asking for items not needed or that already exist in large quantities is often frustrating for volunteers who sometimes go to great efforts to acquire items only to find a large stock of them in the storeroom.

Understanding Repercussions of Good Work

It may be difficult to understand why, in spite of great need, you are not wanted. This is a common scenario and must be diplomatically dealt with as human needs sometimes may call for you to help in a situation where you are needed but not wanted. It must be understood that our acts of charity can have secondary repercussions. For example, how does the local pharmacist feel when we bring in a big box of medication and now his income is undermined? How do the surgeons across town feel when some Americans come and advertise for free surgery? How does the hosting hospital recuperate costs from increasing the hospital census by 500 % with non-paying patients? Although licensing regulations for physicians and import taxes on gifts in kind are often annoying and have been subject to corrupt government processes, it should be understood that the basis behind this is to protect the economic infrastructure of the medical community. There are no easy answers to these questions as the needs of the people are often times dire, and the barriers can sometimes seem insurmountable. An important concept to keep in mind when navigating these issues is to go with the idea that you are helping more than just individual patients. Go with the idea that you are going to help a doctor, an institution, a medical community, and a country as well as the individual patient (Box 14.2).

Keep Your Motives Pure

There are many reasons to do charity work. Travel, adventure, learning, publicity, and feeling good about oneself are some reasons that may motivate surgeons to volunteer, but should be put secondary to the sincere desire to provide a needed service in the most effective way. Is it OK to have ulterior motives as long as we are doing good work and people are getting helped? This is similar to having a conflict of interest with a particular implant company or letting personal economics affect your surgical decision making. Yes, patients can still be helped in a good way, but this can lead to poor judgment and places the priority on benefiting yourself more than the patient—a dangerous place to be.

Credentialing and Liability

Credentialing and medicolegal concerns are becoming more important issues even in resource limited environments and there are a few basic precautions and diplomatic principles

that should be understood. Although it can be liberating to practice in environments where bureaucracy and liability issues do not take precedence over patient care, it must be remembered that, this freedom should not encourage renegade behavior. Doing what is right for the patient should always be your guiding principle and you should make efforts to assure that those working around you realize that. Never should a surgeon work outside his expertise and/or perform procedures that he is not licensed to do in his home country. As a guest surgeon respecting the credentialing rules of a host institution and country is important. Many resource limited countries have licensing provisions for surgeons coming for short periods of time to do charity work. The general motive of the licensing entity in these countries is to protect the economic viability of local surgeons and make sure that there is a minimum standard of quality amongst foreign health care workers. Often times the credentialing process is rather simple or does not exist at all, but no matter what the case, having a gracious attitude and building relationships with the local staff and administration is an important part of the process.

Medicolegal issues are bigger concerns in North America than most other parts of the world. Nonetheless a few precautions are warranted. The issues vary greatly depending on the location, type of patients being treated, and organizational affiliations. Most legitimate organizations can provide some information on the subject and have provisions in place to protect volunteer surgeons. Many times in these environments it is the hospital or international organization rather than the individual surgeon that carries the burden of malpractice. However, one unique and potentially serious issue is the situation of a US surgeon operating on a US citizen in another country. There have been reports of such cases being litigated in the US court system.

Aside from the subject of formal litigation, disgruntled patients often access news media and internet venues that provide an easy and cost free way to damage the reputation of doctors and institutions. Whether the allegations are perceived or real, these types of patients can do significant damage. It goes to emphasize that in any part of the world maintaining good communication with patients can help to maintain a strong reputation and prevent misunderstandings and possible litigation.

Box 14.2. Keys to Successful International Collaboration

- Good communication
- Develop relationships through long-term commitments
- Be humble—first learn and then teach
- Do not overburden the system
- Respect the local infrastructure
- Understand the possible negative repercussions of good work
- Keep your motives pure—do not do the right thing for the wrong reasons
- Do not perform procedures that you are not properly qualified to do

Operative Challenges: Improvise Don't Compromise

Indications

In general, operative indications should follow the same basic concepts in any part of the world. This involves evaluating whether or not the benefits outweigh the risks. As circumstances vary, so does the relative relationship between benefits and risks. Efforts should not be spared in trying to obtain the necessary equipment and expertise to do an operation with the very best quality possible. We cannot let inconveniences and lack of proper equipment dictate what we do. Following the principle of doing it right or not doing it at all is important no matter where the location (Box 14.3).

Economics have to be considered but should not be the most important factor. They can have paradoxical implications in environments where the reuse of external fixation is commonplace. For example, treating a Blount disease with an expensive multiplanar fixator that can be reused many times may be cheaper than using internal fixation. Whereas in North America, those same sophisticated external fixators may be cost prohibitive for correcting a simple uniplanar deformity. The reuse of external fixator equipment can enable the surgeon to operate without regard to the cost of each additional component that is added for strength and/or cosmesis of the external fixator. Return trips to the operating room for adjustments to fixators can be simple and inexpensive in the developing world without the need for third party payers to approve the process.

The indications for limb salvage versus amputation deserve mention here as these are complex issues even in our own country where we understand the economics and many of the cultural issues. The relative importance of functional outcome, cultural views, and cost of reconstructive procedures versus cost of lifetime prosthetic maintenance take a paradigm shift and differ greatly from country to country depending on the availability of prosthetic services. Often times the expectation of performance is different in less developed environments. In economically privileged countries the debate centers on what option is best for high performance in sports and long distance running, whereas in economically challenged situations most people would be happy for any type of mobility as long as they can keep their own leg. With that being said, reluctance should be even higher to perform amputations in resource limited environments even if it means the functional result is not as good or if a more complex operation or leg lengthening process is required. However, multiple attempts to repair a useless limb need also to be avoided.

In the situation where fluoroscopy is not available, certain procedures are impossible to perform. Indications may change based on whether or not fluoroscopy may be available in the future or at another accessible location or whether it is not an option at all. The philosophy of not doing an operation unless it can be done well should be respected. Many times the lack of fluoroscopy can be compensated for by making larger incisions and/or performing more traditional operations such as open, instead of closed epiphysiodeses. The Watson Jones anterolateral approach to the hip is another example of this, allowing visualization of the femoral head and neck for cases that could otherwise be done in a more minimally invasive fashion if fluoroscopy were available.

Perioperative and Anesthetic Considerations

In areas where an extensive infrastructure does not exist, operations must be performed with a wider safety margin. This calls for a careful preoperative evaluation, additional intraoperative precautions, and careful postoperative vigilance.

Preoperative evaluation should be done both by the surgeon and anesthesia staff. It should be realized that in areas where nutritional deficiencies and parasitic diseases are endemic that anemia can be common. Even when preoperative lab evaluations are not routinely indicated in first world settings, it may be prudent to do additional work up in other settings. Sometimes in spite of limited resources, local bureaucracy requires seemingly unnecessary testing which has to be respected by volunteer staff. There are a couple of portable devices which can be extremely helpful in these situations. The HemoCue device (Fig. 14.2a) is a relatively inexpensive piece of equipment (approximately $600 USD) and is an efficient and cost effective way to evaluate preoperative hemoglobin levels (cuvettes cost ~$2 per patient depending on quantity purchased). The i-STAT (see Fig. 14.2b) is approximately $10,000 USD, but is able to perform a variety of tests including CBC, chemistry panels, and blood gases (cartridges ~$8–10 for each point of care test).

Informed consent is something that should not be forgotten. Even if it does not involve a piece of paper, it is important to communicate to patients, family members and even local staff the plan of the procedure and the possible risks and complications. This is especially important for ablative procedures, complex surgery that involves considerable risk, and for procedures that involve gradual corrections and limb lengthening which require additional patient and family commitment.

Intra-operative blood loss needs to be minimized and carefully assessed. It is important for the surgeon to know how to calculate the maximum allowable blood loss (MABL). The following formula is used:

$$\mathrm{MABL} = \mathrm{EBV} \times \left(\mathrm{HCL_i} - \mathrm{HCT_f}\right) / \mathrm{HCT_f}$$

EBV—Estimated blood volume (average blood volume [ml/kg] × weight [kg])
Average blood volume
Neonates 85 ml/kg
Infants 80 ml/kg
Adult men 75 ml/kg
Adult women 65 ml/kg
HCT_i—Initial hematocrit
HCT_f—Final hematocrit (lowest acceptable at end of operation)

Fig. 14.2 (**a**) HemoCue. Reprinted with permission of HemoCue America. (**b**) I-STAT. Reprinted with permission from Abbott Point of Care

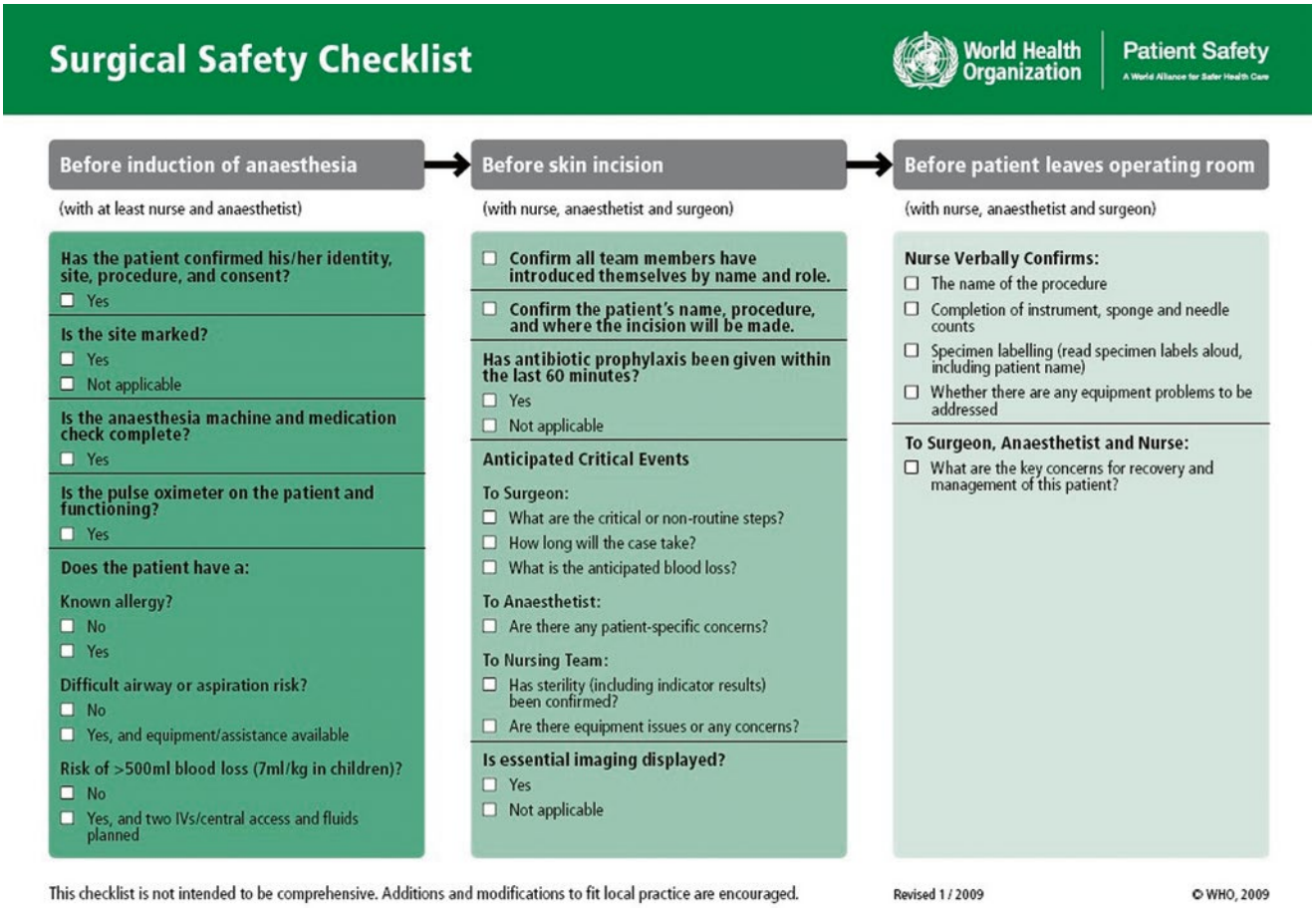


Fig. 14.3 WHO surgical safety checklist. WHO surgical safety checklist, URL: http://www.who.int/patientsafety/safesurgery/en, © World Health Organization 2008 All rights reserved

A healthy patient with a normal starting hematocrit can usually tolerate an acute loss of one third of their blood volume. If you consider that a total estimated blood volume (EBV) is approximately 70 ml/kg (slightly more in infants and less in adult females) then a short way to estimate MABL is to divide 70 ml/kg by three, which is just over 20 ml/kg. *Most patients who are healthy and have normal starting hemoglobin will tolerate 20 ml/kg blood loss without needing transfusion*. In many situations blood may not be available and when it is, often it can take days to obtain. Thus the responsibility lies with the surgeon to make sure that there is a wide margin of safety in regards to surgical blood loss and to always be prepared for the worst possible scenario.

By using these calculations, objective and well informed decisions can be made in regards to performing multiple procedures in one operation versus staging procedures to decrease blood loss. This is especially applicable to children with significant deformities in bilateral lower extremities such as osteogenesis imperfecta, skeletal dysplasias, and rickets. Using the Esmarch bandage as a sterile tourniquet is a safe and effective method of controlling blood loss. Care must be taken to apply it as a wide band tight enough to avoid a venous tourniquet but not overly tight to cause bruising or injury. Any time an Esmarch is used an audible alarm must be set in order to avoid inadvertently leaving it placed beyond 2 h and causing irreversible injury.

The World Health Organization has created a Surgical Safety Checklist (Fig. 14.3) in the interest of reducing surgical deaths and operative morbidity. This is not meant to be a regulatory document but rather a guide to reinforce accepted principles of surgical safety and to promote teamwork and communication. The principles outlined here are basic elements for performing safe operations and should be implemented in every surgical venue.

In the postoperative period, it must be remembered that pain is the fifth vital sign and in North America there is a mindset that less is always better than more. This is not actually in the best interest of patient safety especially in an environment where sophisticated monitors do not line the walls, nurses may not have the latest Pediatric Advanced Life Support credentials, and the code cart is missing or not well stocked. Until an entire infrastructure can be created to remedy these issues then

patient safety should be prioritized over tolerable levels of pain. Fortunately, in these environments patients expect that major surgery will involve some pain and they are much more tolerant of it. As surgeons working in this environment we also need to be trained and updated on resuscitation credentials as we sometimes cannot depend on those around us to do the task.

Sterility

Sterility is a principle that should never be compromised no matter what the situation. A brief discussion is warranted about several options for sterilization, since we as surgeons are not typically involved in the process and do not have the knowledge to assess whether or not various methods provide safe sterilization. In order for something to be considered sterile with autoclave processing, it must reach 121 °C/250 °F with a pressure of 15 psi/100 kPa for 15 min. Indicators are available and should be used routinely. These are an easy and compact addition to the list of essential surgical materials that can be taken on a trip. This can be especially important in situations where aging autoclaves and maintenance schedules may not be strictly adhered to. If a reliable autoclave is not available some portable stovetop units can be acquired and their cost is not prohibitive (Fig. 14.4). These units come in various sizes and can accommodate a variety of surgical instruments; the larger sizes can accommodate larger instruments and implants but are not able to accommodate intact full size instrument trays.

Fig. 14.4 All-American stove-top sterilizer autoclave. Reprinted with permission of Wisconsin Aluminum Foundry

Cidex®

Cidex® is a disinfectant manufactured by Johnson & Johnson that comes in three different variations: Cidex® 14-Day (glutaraldehyde), Cidex® Plus 28-Day (glutaraldehyde), and Cidex® OPA (ortho-phthaladehyde). These provide a fast and effective method of sterilization for a wide variety of instruments and external fixator parts etc. It can be useful for heat sensitive materials that are not destroyed by submersion. When used appropriately Cidex® is bactericidal, fungicidal, tuberculocidal, and sporocidal. Although it can be quite effective, it is very sensitive to dilution, storage methods, expiration dates and duration of use. Similar to opening a carton of milk, it has an expiration date and a limited period of use once opened and poured into a sterilization tray. Due to this variability, it must not be used indiscriminately and we do not use it for implant sterilization. There are indicator strips available which can be helpful to prove efficacy of sterilization.

Ethylene Oxide

Ethylene oxide, known by the trade name Anprolene®, is especially useful for sterilizing heat sensitive materials. It is a highly toxic and explosive gas which was used for making bombs in World War II. It can provide safe and effective sterilization of heat sensitive materials such as gowns, drapes, gloves, Esmarch bandages, Ioban®, cautery pencils, suction tubing, bulb syringes, suture packs (Nylon, Monocryl, Vicryl), and electronic devices (drill, camera, etc.). Most items with the exception of food, drugs, and liquids can be sterilized with ethylene oxide. There are some commercially available processing units that provide ventilation pumps, purge pumps, aeration, and monitors that track cycle progress. Special plastic sterilization bags and ethylene oxide ampules are marketed to be used with these units. For emergencies and austere conditions these plastic sterilization bags and ampules can be safely used without the processing units if appropriate precautions are taken.

Operating Room Set Up

Optimizing every controllable factor includes arranging the operating room furnishings before an operation in order for the operation to proceed as smoothly as possible. Many operating rooms are small and in order to comfortably operate and prevent people from contaminating the field it is important to remove all nonessential pieces of equipment from the

room and arrange the remaining furnishings in an ideal position to work effectively. Don't start operations with the C-arm on the wrong side of the table or the cautery unit inconveniently located. Patient positioning and draping should follow the same philosophy. The surgeon must take the lead and cannot expect all these things to fall into place automatically as may happen with an experienced surgical team at their home institution. It is also essential that equipment outside the operating room is well organized and available at the moment needed. It is not acceptable to have equipment on hand that is either not known about or not available for use at the moment needed. Part of being a good surgeon is to know your equipment and have it prepared to implement the preoperative plan and to also be prepared with a backup plan should the operation take a different direction than anticipated. This sometimes requires spending almost as much time in the storage room organizing equipment and preparing for cases than is spent in the operating room actually doing the cases.

Surgical Modus Operandi in Resource-Challenged Environments

Do not exceed the capacity of the local infrastructure with sophisticated operations that will not be correctly followed up. Placing a Taylor Spatial Frame in an environment where no one knows how to manage it would be an example of this. Also performing highly invasive operations that potentially could result in medical complications that the local infrastructure is not prepared to deal with could be disastrous.

The pros and cons of internal vs. external fixation in a primitive environment have a different dynamic than in the USA. The "one and done" philosophy should be of primary consideration. This means that gradual corrections, which require diligent follow-up and can involve delayed complications, should be avoided when possible. And when internal fixation can be used, it is usually preferable.

Internal vs. External Fixation in Resource-Challenged Environment

Benefits of internal fixation:

- Less postoperative maintenance necessary.
- No pin site infections and less risk of late osteomyelitis.
- Less soft tissue irritation allowing easier range of motion.
- May result in earlier return to function.
- Better for treatment for femoral deformities due to less soft tissue concerns.
- Often does not need to be removed.

Benefits of external fixation:

- Can be applied with minimal incisions.
- If equipment can be reused:
  - Inventory is more easily maintained.
  - Expenses are minimized.
- Enables gradual corrections and bone transport in appropriate situations.
- Facilitates intentional displacement of osteotomies that are performed away from the apex of deformity.
- Postoperative alignment can be more easily adjusted.

Another option is to consider the use of Steinmann pins or K-wires for fixation. This is a very economical approach to osteotomy fixation. In extreme situations bicycle or motorcycle spokes can be sharpened with a small bench grinder, sterilized, and used for fixation. In addition to the biological benefits for making osteotomies in metaphyseal bone, the larger surface area provides more stability and also facilitates stable pin/wire fixation methods. These can be buried under the skin if there is a high risk of infection, but this obligates another procedure for removal. If left in a percutaneous position then a large portion of wire (2 cm or more for most situations) should be left outside the skin and generously bent in order to prevent migration and an otherwise unnecessary return trip to the operating room.

Reuse of Implants and External Fixation Components

The reuse of implants (including plates, screws, intramedullary rods, and bone fixation half pins) is not something that can be universally recommended due to variability in implant strength, size, material, and variability in the magnitude of stress and number of cycles to which it was subjected. Catastrophic failure can occur when cyclic stresses that exceed the endurance limit of a metal are applied to an implant over a given amount of time. The endurance limit is an amplitude of stress below which it appears that even with an indefinitely large number of loading cycles failure will not occur. The endurance limit is usually about half of the ultimate tensile strength of an implant, unless it is notched, which can significantly decrease the endurance limit. Some metals such as aluminum do not have an endurance limit and even small amounts of cyclic stress will eventually cause failure. Titanium and the ferrous alloys like stainless steel are materials that *do* have an endurance limit, meaning that small amplitude (below endurance limit) loading cycles will theoretically not cause failure. Practically speaking, it is not possible to know the magnitude of stress and number of cycles to which an implant has been subjected nor is it possible to visually decipher this with the naked eye. Ultimately, the risks and benefits of reusing an implant must be left up to the judgment of the surgeon. If an implant is reused, it is advisable to carefully examine it, and consider using more robust constructs to decrease the amount of stress on an implant

thus increasing the number of cycles to failure. Using common sense and appropriate reprocessing methods, most implants can be reused without complication.

The implications of reusing external fixators in resource limited environments are different from North America due to perceptions and medicolegal issues. The real question is: What is safe and effective for the patient? In parts of Europe (where resources are not severely limited) and in developing countries fixators are reused on a regular basis. In the USA many external fixators are labeled "single use only." Due to an interest in cost containment and social responsibility many institutions in North America have sought ways to reprocess single use devices (SUDs). The Federal Drug Administration (FDA) has thus classified SUDs into three categories: noncritical risk (level 1), semi-critical risk (level 2), and critical risk (level 3) [5]. The reuse of fixator clamps and bars that do not penetrate the skin are considered level 1 SUDs by the FDA. They have approved various reprocessing protocols for these devices. The reprocessing protocols include cleaning with various solutions to remove all biologic material, dismantling the device, inspection of components for defects or fatigue cracks (usually with magnification or microscope), and re-sterilization.

Biomechanical effects of cyclic loading and patient outcomes with the reuse of fixators have been studied. Matsuura et al. report the effects of various magnitude and quantity of load cycles on the EBI Dynafix external fixator [6]. They loaded one group with 100–450 N of compressive force for three million load cycles to simulate three uses of the device. They found that 17 % of initial stiffness was lost and that some fatigue cracks began to develop at three million cycles. Another group was subjected to higher loads and it was found that fatigue of the device occurred much sooner. Their advice is that external fixators should only be reused a limited number of times and should be carefully inspected. Fixators with more articulating parts certainly are more prone to failure than simple rods and rings. Also fixators that are applied to large patients, highly active patients, and fixators that have been left in place for prolonged periods of time have a higher risk of failure vs. those applied for damage control orthopedics and have only been left in place for a few days or weeks. Several clinical studies have been published showing no loosening of components, no loss of fixation, no increase in pin site infections, and no mechanical failures when reusing fixators [7, 8]. Even if there is a failure of an external fixation device it can usually be resolved with noninvasive and often times nonoperative means.

In spite of these results, commentaries have been published against the reuse of external fixation devices [9] that are not scientifically based, do not apply to limited-resource environments and add fuel to medicolegal fears. The reuse of external fixators can be safely done if the appropriate reprocessing methods and inspection are implemented.

Fig. 14.5 12v cordless variable-speed drill

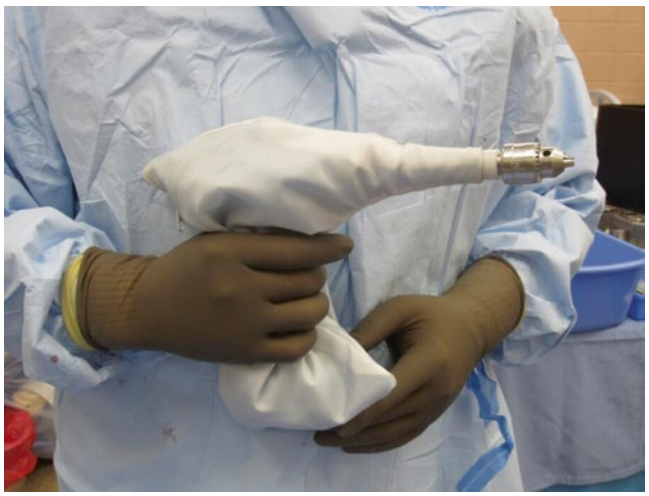
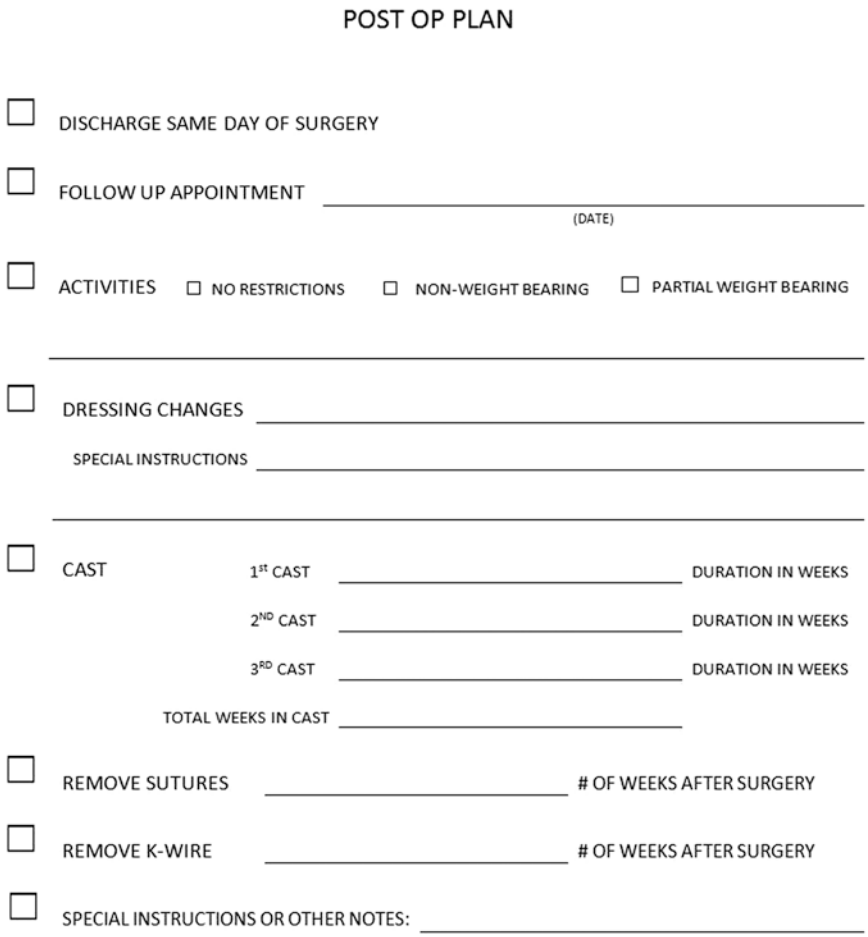


Fig. 14.6 Cordless drill kit shown with sterile cover and surgical chuck

Cordless Power

Many orthopedic operations require a power drill. In limited resource environments the prohibitive costs of the systems that are on the market have led us to develop a safe and effective alternative (Figs. 14.5 and 14.6). We utilize a common hardware store drill with a sterile surgical cover and stainless steel surgical chuck. We use a 12-v cordless variable speed drill with revolutions up to 1,050 rpm. Drills that function at rpms above 1,500 in general are not appropriate for orthopedics as they create excessive heat and can cause osteonecrosis. The stainless steel surgical chuck is custom made in order to facilitate the use of K-wire placement and convenient loading of various drill bits and it can withstand the demands of harsh solutions and repeated cycles of steam sterilization. The system is used with an impervious cover that can also be autoclaved. Theoretically, any drill could be

Fig. 14.7 Post-op plan


POST OP PLAN

☐ DISCHARGE SAME DAY OF SURGERY

☐ FOLLOW UP APPOINTMENT _____ (DATE)

☐ ACTIVITIES ☐ NO RESTRICTIONS ☐ NON-WEIGHT BEARING ☐ PARTIAL WEIGHT BEARING

_____

☐ DRESSING CHANGES _____

SPECIAL INSTRUCTIONS _____

_____

☐ CAST 1ST CAST _____ DURATION IN WEEKS

2ND CAST _____ DURATION IN WEEKS

3RD CAST _____ DURATION IN WEEKS

TOTAL WEEKS IN CAST _____

☐ REMOVE SUTURES _____ # OF WEEKS AFTER SURGERY

☐ REMOVE K-WIRE _____ # OF WEEKS AFTER SURGERY

☐ SPECIAL INSTRUCTIONS OR OTHER NOTES: _____

made sterile using ethylene oxide and thus not require special covers and surgical grade chucks; however, fluids and biomaterials can easily enter vent holes and damage the internal components of the drill. In addition hardware store quality drill chucks used in this fashion do not stand up to the rigors required for appropriate cleaning and reprocessing.

Postoperative Care

At the end of any operation, good documentation is essential. This includes writing clear orders, an operative note with all significant aspects of the operation including implants used, and some clear postoperative instructions. We have found it helpful to use a premade form for a detailed postoperative plan that includes dates of follow-up, physical therapy instructions, casting, dressing, and suture removal instructions as well as any specific needs such as antibiotics (Fig. 14.7). If you are not likely to be present at the time of follow-up, it is even more important to leave detailed instructions that can be easily understood by local staff. Leaving your contact information with the local surgeon or directly on the operating note should be made a routine. Most importantly, the patient must be able to easily access someone who is knowledgeable of the operation and capable of managing any possible complications. Thankfully the ease and accessibility of international communication allows us to follow up remotely in ways never before possible.

Other Aspects of Orthopedics in the "Wild"

Certain surgeons are attracted to a swashbuckling mindset that leads them to perform difficult operations in the most austere of conditions. Performing operations without the appropriate facilities and equipment should not be seen as a badge of honor, as it is mandatory to adhere to some minimum requirements for safely performing operations. These include running water and reliable electricity and lighting, as well as an intact operating room which provides a well-protected barrier to the outside elements. As previously discussed, safe sterilization, safe anesthesia, adherence to basic principles of sterile technique and stable orthopedic fixation are essential. These are factors that the surgeon should have

control over. Surgical risk and the difficulty of performing operations are increased when doing surgery in the "wild." Some of these factors are controllable and others are not. Factors such as biology, patient compliance, and limitations in available resources and personnel are largely uncontrollable. The surgeon must optimize all controllable factors and take extra precautions to assure patient safety and stable fixation in spite of other uncontrollable risk factors This may mean added points of fixation—extra bone pins on a fixator or more robust plating patterns than would otherwise be necessary. Often times, communication is difficult and follow-up is scant; thus, it is necessary to build constructs not prone to failure and take extra precautions in order to avoid complications. This also involves extra efforts communicating with local staff and patients.

Box 14.3. Improvise—Don't Compromise

- Techniques may need to be modified in situations of limited resources but surgical principles and expected outcomes should never be compromised
- Understand the capabilities and resources of your anesthesia team
- Do not perform operations whose complexity and risk exceeds the capacity of the post operative infrastructure
- Be extra careful about surgical safety while working in environments that may not have implemented the safety measures you are accustomed to
- Opioids must be used judiciously in environments lacking appropriate monitoring, resuscitation equipment and properly trained personnel
- Principles of sterility and sterile technique should never be compromised
- Make sure your equipment is prepared and your operating room properly arranged before embarking on an operation
- Principles of stable fixation should not be compromised and constructs should often be made more robust if limited follow-up is expected
- Economize
- Be flexible

Specific Techniques

Clubfoot

Clubfeet seen in resource limited environments are not usually like the ones typically seen by surgeons in North America. In addition, the success of Ponseti casting is making the operative treatment of clubfoot a lost art. Often times in these environments, severe clubfeet are present in older children, and those who have had prior surgery. For this reason a review of the surgical options for clubfoot is briefly described here.

The Ponseti treatment for clubfoot has revolutionized the treatment of clubfoot around the world. The results of this treatment have been shown to be superior to previous methods of casting and/or surgery [10–12]. The most rapid corrections with Ponseti casting are seen in newborns; however, the technique continues to be effective in older children as well. When performing casting, it is important to follow all of the details of the Ponseti technique to get the very best results. These include: supinating the forefoot to lock the metatarsal cuneiform joints in order to concentrate forces at the subluxed talonavicular joint, placing long leg casts in order to provide sufficient abduction of the forefoot, and performing percutaneous Achilles tenotomy in nearly all cases.

Neglected and recurrent clubfeet are a common cause of disability in developing countries. The stigma of this deformity often prevents those who have it from going to school, integrating into society, and having a job. In older children and adolescents the correction of the deformity has been shown to be worthwhile for social reasons in spite of the fact that often times it does not restore normal mobility and shape to the feet [13].

The excellent results and logistics of effectively implementing the Ponseti method add complexity to surgical decision making when patients in limited resource environments are unable to return for weekly casting, or when short term humanitarian surgical trips do not permit the luxury of providing treatment over time. Ultimately, the best outcome for the child is what should be sought. The surgeon must remember that no child has ever died just because they had a clubfoot, and that a poor surgical result is worse than a deformity not previously operated. Thus immediate operative treatment may not be in the best interest of all patients. Every possible effort should be made to cast clubfeet even if an operation will ultimately be necessary. In situations where casting is logistically difficult, an accelerated program has been described where casting is done every 5 days and has been shown to give similar results to the typical 7-day protocol [14]. Even faster protocols have been tried but are not recommended due to the amount of swelling that can occur and diminishing returns in speed of correction.

In cases where operations are required, casting can be a helpful preoperative adjunct to surgery. Sometimes even just a few days of casting can improve operative results, decrease wound complications, and facilitate the ease of an operation. A hybrid approach can be taken where a minimal release (including posterior tibialis tenotomy, plantar fasciotomy, and Achilles lengthening) is combined with preoperative and postoperative casting for cases where extensive casting is difficult or not practical. There is much debate about the

Table 14.2 Surgical options for neglected and recurrent clubfoot[a]

Posteromedial release	Soft-tissue release for cavus, adductus, varus, and equinus	• Cincinnati • 2 incision • Turco
Additional procedures	Treatment of residual adductus	• Calcaneal closing wedge • Lichtblau calcaneal resection • Calcaneo-cuboid wedge resection/arthrodesis
	Treatment of residual equinus	• Excision head of talus • Naviculectomy • Distal tibia osteotomy
	Treatment of residual heel varus	• Calcaneal osteotomy (lateral slide)
	Treatment of residual supination	• Tibialis anterior transfer • Medial cuneiform osteotomy • Trans cuneiform osteotomy
	Wound closure difficulty	• Leave wound open • Immobilize under-corrected then serial casting postoperatively • Dorsal foot rotational flap • Distal tibia shortening osteotomy
Salvage procedures (for severe and recurrent clubfoot)	Older child with stiff/severe deformity	• Triple arthrodesis—Lambrinudi modification • Posterior release with midfoot dorsal closing wedge
	Arthrogryposis and myelomeningocele	• Talectomy
External fixation	Ilizarov or Taylor Spatial Frame for recurrent/residual deformities and severe clubfoot	• Soft-tissue distraction • Distraction osteogenesis (osteoplasty)

[a]Adapted with permission from Penny NJ. The neglected clubfoot. Tech Orthop 2005; 20(2):153–166

maximum age limit for effective casting. In reality there is no specific age at which casting becomes ineffective; although the time and materials required to correct the clubfoot deformity can significantly increase with age and stiffness of the foot. This is due to progressive ossification of the foot bones. As the child becomes older there is less cartilage and less remodeling potential in the foot.

Posteromedial release has traditionally been a standard treatment for clubfoot. Due to the successful implementation of the Ponseti method in North America this operation is becoming less common. However, in severe, recurrent, or neglected clubfoot, especially in older children, it is still a viable option. For children with significant adductus, posteromedial release can be combined with a lateral column shortening osteotomy (a Lichtblau anterior calcaneal resection, calcaneal cuboid wedge resection, or calcaneal shortening osteotomy). Other options for residual deformities including residual equinus, heel varus, or forefoot supination are outlined in Table 14.2. In older children with severe deformities, triple arthrodesis is often necessary. This can be done in children as young as 8 years old, especially in bilateral cases where a foot size discrepancy would not be created. Another option that has been performed with success for severe cases is a posterior release with a dorsal closing wedge midfoot osteotomy. The temptation to correct recurrences and residual deformity, particularly in the 5- to 12-year-old age group, needs to be weighed against expected results, risk, and recuperation time. In many cases it is best to avoid repeated surgery and wait until a definitive operation like triple arthrodesis can be performed at an age closer to skeletal maturity. The reader is referred to the excellent article by Norgrove Penny for a detailed description of the options and techniques for neglected clubfeet [15].

Previously operated and neglected clubfoot can also be managed with the use of external fixation. Two basic methods of foot deformity correction using Ilizarov techniques are: (1) soft tissue stretching (correcting through joints) and (2) bony correction (osteotomies) with distraction osteogenesis. Due to the improved ability to correct rotational deformity with Taylor Spatial Frame (TSF), we have applied this to clubfeet in a fashion that simulates Ponseti casting (correction through soft tissue). Other fixator configurations with or without osteotomies are also effective. Any of these methods require experience and an infrastructure that can support close follow-up and postoperative management. One of the biggest risks with external fixation is the risk of recurrent deformity. The long treatment time, possibility of persistent hyperesthesia, and other complications need to also be considered when entertaining the use of gradual distraction for surgically treating older children.

SIGN Nail

The SIGN nail (Surgical Implant Generation Network, www.signfracturecare.org) is an intramedullary locking nail which can be implanted without fluoroscopy. It is made by a nonprofit organization for use in limited resource environments

Fig. 14.8 Hip spica application. After appropriate anesthesia, the patient's torso is placed supine on the end of the armboard. Three assistants are used to stabilize and position the patient's arms/head region and each of the lower extremities. Standard casting materials, including a temporary towel to pad the patient's back, are used to complete the hip spica cast. Reprinted with permission from Pasque C, Harbach G. Hip spica application using an operating table armboard. J Pediatr Orthop 2000; 20(6)

and made available to surgeons and institutions at minimal cost. This has revolutionized long bone fracture care around the world with more than 120,000 cases performed. SIGN has established programs in more than 55 countries where surgeons have had the necessary training and experience. Accountability, quality control and maintenance of a sustainable inventory are realized through the use of a database that requires uploading of preoperative and postoperative images as well as input of case data and implant use. There is a learning curve to using the system, which has some unique features enabling distal interlocking without X-ray guidance. This system is useful in limb deformity correction when stabilizing osteotomies or even performing lengthening over nails. Fixator assisted nailing is also a useful technique for a variety of long bone deformities. There is a pediatric version of the SIGN nail available; however, the standard nail is suitable for a trochanteric entry and may be used in older children. The pediatric nail is more useful for fractures and has a unique distal interference fit without a distal interlocking option. The standard adult nail comes in sizes as small as 8×200 mm, making it versatile for deformity corrections in relatively small patients.

Spica Cast

Many pelvic and femoral osteotomy surgeries involve the use of a postoperative spica cast. It is mentioned here to highlight the fact that a specialized spica table is not necessary nor may it be available in many resource challenged environments. Spica casts can be applied on a simple arm board (Fig. 14.8) [16]. A plank of wood or other material ideally about ½″ thick and about 4″ wide can be slid under the pad on the operating table and be used for both an arm board and spica table. In order to do this, the board is placed at 90° to the table under a thin mattress and sticks out to the side like a diving board. One person stabilizes the proximal end of the board onto the table as well as the torso of the child who is placed over the side of the bed on the opposite end of the board. Bilateral and unilateral spica casts can be placed on any size child with the appropriate size arm board.

Educational Resources

Having a collection of orthopedic textbooks available on a laptop or iPad is very helpful when performing orthopedics in resource-challenged environments. Many times demands are made to perform difficult operations that one may not commonly perform. The surgeon must first assess his/her own abilities and again remember that a poorly performed surgery is best not performed at all. But a review of operative details and often a consult from a colleague can remind one of the details needed to efficiently perform a quality operation and prepare the proper equipment for a variety of operations that you may not routinely perform. Fortunately, most textbooks are now available in electronic formats which can allow one to maintain an entire orthopedic library on a small electronic device. The Global Help Website www.global-help.org has a wide variety of textbooks and monographs available for free. They have an excellent monograph on the Ponseti treatment of clubfoot which has been translated into more than 20 languages and serves as an educational tool both for surgeons and parents. Other patient specific educational materials are available on this site as well. An excellent resource is their "Pediatric Orthopedic Library," which on a single disc contains the *Atlas of Pediatric Orthopedics Surgery* (3rd Edition) (Morrissy and Weinstein); *Bibliography of Orthopedic Problems in Developing Countries* (Spiegel); *Lovell & Winter's Pediatric Orthopedics* (5th Edition) (Morrissy and Weinstein); *Neuromuscular Disorders; Practice of Pediatric Orthopedics*

(Staheli); *Sequelae of Septic Arthritis of the Hip* (Spiegel, Penny, and Shrestha); *Standards in Pediatric Orthopedics* (Hensinger); *The Easter Seal Guide to Children's Orthopedics* (The Easter Seal Society); *What Parents Should Know About Flatfeet* (Staheli, Staheli, and Mosca). The DVD cost is $1.00 USD. This allows a traveling surgeon to carry a huge library and moreover offer an invaluable gift to the local surgeons for an extremely low cost.

HINARI (Health Inter Network Access to Research Initiative) is a World Health Organization program which provides free or very low-cost online access to up to 35,000 information sources/journals in biomedical and related social sciences to *local, nonprofit institutions* in developing countries. This functions as an institutional subscription to journals referenced by PubMed etc. An application process is required, and in the most resource challenged countries, subscriptions are completely free of charge, whereas in other developing countries a small fee is assessed. More information and application materials can be obtained at www.who.int/hinari/en/.

Summary

Working with limited resources and often times in unfamiliar locations can be some of the most challenging but also most rewarding experiences in life. Many of these operations are life changing for the patients we treat. Basic principles should never be compromised; every effort should be made to obtain outcomes equal to those where ample resources exist. This often requires more robust fixation, extra precautions to avoid complications, and clear communication. As orthopedic surgeons with education and resources, we should consider it our obligation to help those who are in need regardless of their ability to compensate us. This can be in our own country or another. By going beyond stagnate and repetitive routines, new perspectives are gained, new relationships are built and lives are changed.

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