

Injuries in Developing Countries—How Can We Help?

The Role of Orthopaedic Surgeons

Lewis G. Zirkle Jr MD

Published online: 7 August 2008
© The Association of Bone and Joint Surgeons 2008

Abstract Each year nearly 5 million people worldwide die from injuries, approximately the number of deaths caused by HIV/AIDS, malaria, and tuberculosis combined. Ninety percent of these injuries occur in developing countries and that number is growing. Road traffic accidents account for 1.2 million of these 5 million deaths. For each death from trauma, three to eight more are permanently disabled. Orthopaedic surgeons should consider the victims of this epidemic by using their ability and capacity to treat these injuries. SIGN (Surgical Implant Generation Network, Richland, WA, USA) builds local surgical capability in developing countries by providing training and equipment to surgeons for use in treating the poor. It assists in treating long-bone fractures by using an intramedullary nail interlocking screw system. C-arm imaging, unavailable in many of these hospitals, is not necessary to accomplish interlocking. Surgery is performed primarily by local surgeons who record their cases on the SIGN surgical database. Discussion of these reports provides a means of communication and education among surgeons. This database demonstrates the capability of these surgeons. It also demonstrates that the SIGN intramedullary nail is safe for use in the developing world as it has been successful in treating 36,000 trauma patients.

Introduction

Each year nearly 5 million people worldwide die from injuries [1]. This is approximately the number of deaths caused by HIV/AIDS, malaria, and tuberculosis combined [6, 7, 8]. Ninety percent of these injuries occur in developing countries [2, 3, 5, 8].

An additional 20 to 50 million people are injured annually in road traffic accidents [4]. Many of these severe injuries include long bone fractures. Road traffic accidents, which cause a large majority of trauma injuries, are a disease of emerging prosperity. Rural people migrate to the cities where they secure jobs. They travel back and forth from their homes to these jobs. As a family accumulates money, the first purchase is often a motorbike, which becomes the family vehicle. New roads are being built at a much slower rate than the increased number of vehicles. The rule of the motorbike is the rule of the road.

Lower-level (“district”) hospitals that initially treat a large number of injured patients are not equipped to handle the increased number and severity of injuries often caused by road traffic accidents. Patients with severe injuries are usually referred to larger hospitals. Patients must purchase their implants for fracture stabilization prior to surgery. The cost of these implants makes them inaccessible for many patients. Outcomes are particularly bad for open fractures, which should be treated in a timely manner. Often times even IM nail systems that require interlocking with a C-arm are not available.

Surgeons in developing countries usually work in government hospitals for 6 to 8 hours per day and then spend the rest of their day working in a private practice. Anesthesiologists and nurses also work the same hours, ending surgery by 2:00 p.m. each day. Emergency surgery after these hours occurs in special operating rooms. Most

The author certifies that he founded and is president of SIGN, a non-profit entity, but does not receive payments or benefits from that entity.

L. G. Zirkle Jr (✉)
Surgical Implant Generation Network (SIGN), 451 Hills St.,
Suite B, Richland, WA 99354, USA
e-mail: signcom@sign-post.org

surgeons are willing to stay later if they have operating time. This protocol is the same for surgeons in the majority of developing countries. These surgeons treat more fractures than surgeons in United States because 90% of severe fractures occur in developing countries [2, 3, 5, 8]. These surgeons are innovative, technically proficient, and are able to insert implants using tactile sense rather than visual aids such as C-arm imaging. They are credentialed surgeons and evidence of their skill and expertise can be seen in their surgical reports and witnessed in their patient interaction.

I will describe an approach that demonstrates how, with access to both mentors and affordable technology, surgeons have the opportunity to better serve their patients with long bone fractures. The students then become the teachers, and they are eager to learn and share their knowledge. I learn from them each time I visit.

History of SIGN

I formed the Surgical Implant Generation Network (SIGN) (<http://www.sign-post.org>) in 1999, with a vision of creating equality of fracture care throughout the world. The sentinel event came when I saw a patient who had been lying in traction with a nonunited femur fracture for 3 years! Surgeons in this hospital knew to treat the fracture, but the patient could not afford the implant. I suddenly realized that teaching the treatment of long bone fractures had to be accompanied by a sustainable supply of implants which were affordable and appropriate to the local conditions. I then developed a system for the nailing of long bone fractures which could be implanted without the need for a C-arm.

The first challenge was to develop a targeting system that would locate the distal interlock. Initial attempts to design such a device that would interlock without using a C-arm took place in a garage. The nail was made by hand, and did not meet adequate manufacturing standards to meet the demands of orthopaedic surgery. We then progressed to making nails on a hand-milling machine. After producing only one nail in 1 day, we quickly realized the futility of this approach. Randy Huebner, founder of Acumed, recognized our vision. Acumed helped us manufacture the first set of SIGN instruments and nails in 1999. SIGN headquarters in Richland, Wash., now manufactures *low-cost* instruments and implants that are FDA-approved for use in the United States (Fig. 1). The FDA designation is important as an assurance of the quality of our design, materials, and manufacture. These implants are distributed free of cost to designated SIGN centers in developing countries. Design features have evolved over the years, in response to helpful suggestion from SIGN surgeons, as discussed below.

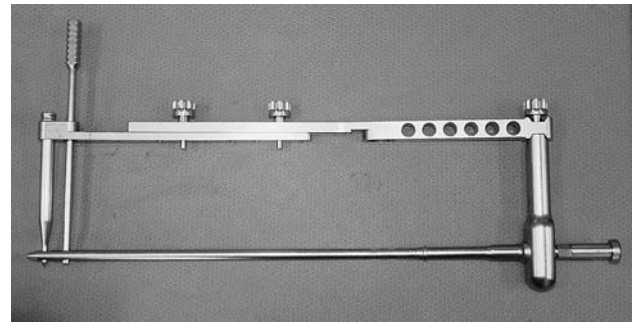


Fig. 1 The target arm, located at the top of apparatus, sits parallel to the SIGN nail, located below, and provides guidance for surgeons to use the slot finder, located to the left, to locate the distal slots of the nail.

While the system has been utilized at a variety of facilities in low income countries throughout the world, the SIGN techniques and implants have also been used in the setting of disaster relief, for example in Banda Aceh when the catastrophic tsunami struck in December 2004, and also following the earthquakes in Pakistan and Java. International surgeons, friends of SIGN, call us to help in times of disaster. The SIGN team begins work immediately after arrival on location, providing surgical training to surgeons as well as performing surgery on disaster victims. SIGN has also had a special interest in treating fractures in patients caught in the midst of armed conflict. Rick Wilkerson, MD, and I visited Iraq in March 2007. SIGN now has three programs in civilian hospitals in Iraq. Jeanne Dillner, CEO of SIGN, Dave Templeman, MD (Minneapolis, MN), and I visited Afghanistan in January 2008 to start two new SIGN programs. This was in addition to a previously established program and two programs run by Emergency (NGO based in Milan, Italy). These two new programs have reported 80 surgeries in the past 3 months. The local surgeons are extremely skilled, and have been very receptive to using SIGN for their patients.

Concept of the SIGN Implant System

The SIGN nail was designed as a tibia nail with a 9° bend proximally and a 1.5° bend distally (Fig. 1). The nail is straight between these bends. We have found a straight nail adequate for stabilization of femur fractures throughout the world. The nail is solid, which might play a role in our low infection rate. The apertures in the nail are slots rather than holes, except for the most proximal of them. This promotes axial compression at the fracture site. Hand reamers are used. The bone from the reamer flutes is saved to be placed in the fracture site during open reduction. An open reduction is required in most cases, as a majority of patients present late (often weeks following

injury), and surgery is often delayed due to a backlog in surgical cases.

We noticed on radiographs reported to the database that some fractures were not compressed after nailing. We improved our extractor and combined it with the instrument to compress the fracture after implantation of the nail and distal interlock. Other design improvements have been made at the request of our overseas surgeons or stimulated by observations in the database.

The early instruments could only target the proximal interlock. SIGN realized that distal interlocking screw fixation was essential, and developed a mechanism to accomplish this without using a C-arm. We use a combination of a target arm followed by mechanical devices to locate and guide placement of holes in the cortex and insertion of interlocking screws through the slot of the nail (Fig. 1). This system was originally designed for use in Vietnam, where most patients have soft bone. When it was taken to Bangladesh, our experience suggested that the bone density was greater in this population, which required some modifications in technique. For example, the large drill bit skived off the bone when we attempted to drill a hole in the near cortex. We devised a step drill that can enlarge the hole after a pilot hole has been made. The slot finders, which are used to locate the slot in the nail, are then placed through this hole in the near cortex. Several modifications of these slot finders have been devised. The final slot finder inserted is cannulated, so that it guides the drilling of the hole in the far cortex (Fig. 1). C-arm imaging is not necessary for this technique.

Surgeons began to use the SIGN nail for other fractures because in many hospitals it is the only nail available. Originally designed as a tibia nail, the SIGN nail has been used for femur fractures (antegrade and retrograde insertion), humerus fractures, and for ankle arthrodesis. We considered changing the anatomy of the nail to suit the anatomy of different bones, but modifications in technique have made this unnecessary.

Education of the Surgeons

SIGN programs have been started in response to requests from surgeons in developing countries. The first four pilot programs were in Vietnam, Thailand, Indonesia, and Nepal. We wanted to see if the concept of donating complete sets of instruments and implants to be used for the poor would work. Orthopaedic, governmental, and political implications were easily worked out as local surgeons and patients saw the value of our system. The surgeons in these developing countries quickly became advocates, and their insights led to evolution in the design of the system. In addition, they also expanded the indications for use of the

SIGN implants. These surgeons disseminated information about the system at national and regional conferences, and presented their results. We soon had more requests to start SIGN projects in neighboring hospitals, and in other countries. Selected hospitals have assumed the role of regional training centers for SIGN and orthopaedic trauma. Surgeons in these hospitals have taught and continue to teach fellow surgeons from their own country and adjacent countries. With their efforts, nearly 3,000 surgeons have been trained in the SIGN technique. Our credentialing process is based on recommendations from international SIGN surgeons. They endorse surgeons who are interested in SIGN, along with their hospitals, as prospective SIGN programs.

Each surgery is reported to the SIGN surgical database (Fig. 2), and more than 18,000 SIGN surgeries have been documented since 2003. These reports, which include pre- and postoperative radiographs, facilitate communication and interactive education. We respond to each report. Indications for use of the SIGN nail have expanded by adapting ideas suggested by surgeons in their reports. The database (Fig. 2) was revised in 2007 by the Orthopaedic Trauma Association (OTA) to provide more information and to verify the trends we see in surgical reports. Examples of these modifications include recording the number of screws used, different approaches, necessity to plate the fibula in distal tibia-fibula fractures, and management of proximal femur fractures. SIGN has been unable to perform a comprehensive analysis of union rates or complications using this database, as followup data has been especially difficult to acquire in these environments. In these countries, patients rarely return for followup when they are doing well, and are reluctant to pay for radiographs when they do return. Followup has been obtained in approximately 30% of patients, and individual program reports note an infection rate of approximately 2% in open and closed fractures combined. We evaluated the radiographs of patients who had full painless weight-bearing. Many still had radiolucent lines, which closed at about 9–12 months post fracture. We are also gathering data to look at the clinical versus radiological result of treating nonunions using the SIGN technique. The database also serves as a guide for scheduling manufacturing. Replacement implants are shipped to a hospital after 20 surgeries have been reported.

Within this network of surgeons, knowledge about the treatment of fractures flows both ways. This interchange is facilitated in a variety of ways, such as the comments section posted by surgeons on the database (Fig. 2), regional conferences in host countries, and the annual SIGN conference in Richland, Washington. At SIGN conferences, surgeons from around the world present their ideas and experiences, and leaders of the OTA and other organizations have participated in these conferences. Because orthopaedic surgeons in developing countries are

The screenshot displays the SIGN Surgical Database interface. At the top, it shows navigation tabs for 'Surgical Cases', 'Surgeons', 'Surgical Codes', and 'Research'. Below this, there are fields for 'Patient Name', 'Case Number', 'Date of Injury' (10/11/2007), and 'Date of Surgery' (11/12/2007). The main section is titled 'Edit fracture information' and includes various form fields: 'Surgeon(s)', 'Fracture Side' (Left/Right), 'Surgical Approach' (Retrograde Femur), 'Location of Fracture' (Proximal, Middle, Distal, Segmental, Femoral neck, Intertrochanteric), 'Type of Fracture' (Closed), 'Nonunion' (Yes/No), 'Previous Implant Used' (Yes/No), 'Check All that Apply' (External Fixation, IM Nail, Wire, Plate), 'Method of reaming' (Hand), and 'Fracture reduction' (Open/Closed). A 'Comments' box contains text about a patient's history with a nail and surgery. Below this are sections for 'Enter Nail Information' (Type of nail, Length, Diameter) and 'Enter Screw Information' (Screw length, quantity of proximal and distal screws). The 'X-Ray Images' section shows four images: three 'Pre-Op' images from October 13, 2007, and one 'Post-Op' image from November 13, 2007. At the bottom, there are 'Cancel' and 'Save & Continue' buttons.

Fig. 2 SIGN surgeons use the database to report surgeries, ask questions, and make suggestions for expanded indications of the SIGN nail.

often called upon to lead the entire trauma team in their hospital, speakers address many unique issues they face. In addition to a large series addressing the treatment of long bone fractures, conference topics also include treatment of polytrauma, soft tissue reconstruction, and addressing the sequelae of fractures, such as correction of bony deformity

using other techniques such as the Ilizarov. After the conference this year, Scott Levin, MD, is arranging a workshop on soft tissue flaps at Duke. Surgeons from many different backgrounds have become friends at these conferences, and have united in their quest to improve the treatment of fractures in various environments.

Partner Organizations

Emergency, MSF (Doctors without Borders), and CURE have facilities in developing countries, and we work with them to supply SIGN systems. Operation Rainbow, COAN, and CAMTA are orthopaedic volunteer organizations interested in serving patients in specific parts of the world. They take our system with them when they travel. Partner organizations in the United States include OTA and AAOS.

Discussion

SIGN has been successful in building capacity in 49 developing countries (Appendix 1), and represents a worldwide network of surgeons exchanging ideas and growing professionally. These surgeons, working towards a common vision, have built lasting friendships that promote peace in the world. SIGN respects the ability of these surgeons and believes in providing them with training, so that they may go on to train others and contribute to the evolution of the SIGN implants and their application. However, the greatest value of SIGN lies in service provision, as effective treatment of long-bone fractures limits disability, and reduces the burden on the patient, his or her family, and the society.

The concept of SIGN is to embrace and empower surgeons in developing countries as our partners, and facilitate affective treatment for marginalized, poorer segments of the population suffering from long-bone fractures. I respect the fact that surgeons abroad must use their tactile senses, whereas we in the United States use imaging to reduce fractures and place interlocks. I personally enjoy this method of surgery. Many people become orthopaedic surgeons because we enjoy “using our hands.” These skills must be developed by repetitive use and experience. When using tactile senses your body image extends to the end of a hand reamer or the end of a nail, or using a slot finder to locate the slot in the nail. This is the opposite direction in which surgeons in the United States are headed, with more imaging and navigation available in the operating room.

SIGN has expanded to 144 hospitals in 49 countries. There are 14 new SIGN programs in 2008 thus far, and a list of hospitals requesting to develop SIGN programs. Future plans also include the development of new products

including hip fixation devices, bone transport systems, and better clamps to facilitate open reduction. The design and manufacture process at SIGN is specific to patients' needs. These new developments must be tailored for use in operating rooms in developing countries. SIGN concentrates on efficient open reductions with internal fixation because fracture patients often arrive at the hospital after partial healing has occurred.

SIGN is just beginning to impact the treatment of the millions of fractures that occur in poor people and in conflicted areas in developing countries. We intend to increase the number of programs as funding allows. We hope to develop stabilization devices for fractures in different parts of the body in addition to the hip. These must be developed for use with the equipment available in

developing countries. We are developing ways to use orthopaedic principles for closure of open wounds, correction of deformity, and treatment of infected nonunion. SIGN will gradually achieve these goals through the help of many individuals throughout the world. We must evaluate our ideas, evaluate the reports on our database, and present our results at conferences. All of us must recognize the emerging epidemic of trauma and assist in the treatment of patients who cannot afford adequate care. It is our duty as orthopaedic surgeons to play a key role in creating equality of fracture care throughout the world.

Acknowledgment I thank the many orthopaedic surgeons around the world and others too numerous to mention who contribute to the expansion of SIGN.

Appendix 1. Active SIGN Hospital Programs

Country	City	Hospital name
Cameroon	Banso	Banso Baptist Hospital
	Bamenda	Mbingo Baptist Hospital
Democratic Republic of the Congo	Goma	HEAL Africa Hospital
Egypt	Cairo	Al Hussien University Hospital
	Cairo	Elzahraa University Hospital
Ethiopia	Wolaitta Soddo	St. Lukes Hospital
	Addis Ababa	Tikur Anbessa Specialized Hospital
Kenya	Mombasa	Coast Province General Hospital
	Eldoret	Eldoret Hospital
	Embu	Embu Provincial General Hospital
	Nairobi	Kenyatta National Hospital
	Kijabe	Kijabe Hospital
	Nairobi	Masaba Hospital Limited
	Eldoret	Moi University
	Kisumu	Nyanza Provincial General Hospital
	Nyeri	Nyeri Provincial General Hospital
Lesotho	Maseru	Queen Elizabeth II
	Monrovia	John F. Kennedy Medical Center
Liberia	Lilongwe	Kamuzu Central Hospital
	Blantrye	Queen Elizabeth Hospital
Mozambique	Maputo	Hospital Central de Maputo
Niger	Niamey	Hospital National de Niamey
	Galmi	SIM Galmi Hospital
Nigeria	Abakaliki	Ebonyi State University Teaching Hospital
	Gombe	Federal Medical Center
	Osogbo Osun	Lautech Teaching Hospital
	Ile-Ife Osun	Obafemi Awolowo University Teaching Hospitals Complex
	Port Harcourt	Port Harcourt Hospital—MSF
	Ile-Ife	SDA Hospital
	Calabar	University of Calabar Teaching Hospital

Appendix 1. continued

Country	City	Hospital name
Rwanda	Kigali	Central Hospital University of Kigali
South Africa	Umtata	Bedford Hospital
Swaziland	Mbabane	Mbabane Government Hospital
Tanzania	Mwanza	Bugando Medical Centre
	Mbulu	Haydom Lutheran Hospital
	Arusha	Selian Lutheran Hospital
Uganda	Kumi	Kumi Hospital
	Kampala	Mulago Hospital
Zambia	Lusaka	Cure International Hospital—Lusaka
	Lusaka	University Teaching Hospital
Afghanistan	Kabul	Central ANA Hospital
	Kabul	Cure International Hospital—Kabul
	Kabul	Emergency Hospital Kabul
	Lashkar-gah	Emergency Hospital Lashkar-gah
	Mazar	Mazar Military Hospital
	Kabul	Wazir Akbar Khan Hospital
Bangladesh	Comilla	Comilla Medical College Hospital
	Malumghat	Memorial Christian Hospital
	Dhaka	NITOR
	Rajshahi	Rajshahi Medical College Hospital
Bhutan	Thimphu	JDWNRH
Cambodia	Phnom Penh	Calmette Hospital
	Battambang	Emergency Surgical Centre
	Phnom Penh	Kossamak Hospital
	Phnom Penh	Preah Ket Mealea Hospital
	Phnom Penh	Preh Batnordum Sihanuok
	Svay Rieng	Svay Rieng Referral Hospital
	Takeo	Takeo Provincial Referral Hospital
Fiji	Suva	Colonial War Memorial Hospital
India	Ludhiana	Gurdev Hospital
	Mumbai	Holy Spirit Hospital
	Kolkata	JN Roy SSB General Hospital
	Kerala State	Koyili Hospital
	Mumbai	Smt. B. C. J. Hospital
Indonesia	Surakarta	Dr. R. Soeharso Orthopaedic Hospital
	Makassar	RS Wahidin Sudirohusodo
	Jambi	Rumah Sakit Umum Raden Mattaher Hospital
Iraq	Mosul	Al-Jumhoori Teaching Hospital
	Erbil	Erbil Teaching Hospital
	Erbil	Shefa Private Hospital
	Sulaimanya	Teaching Hospital
Myanmar	Yangon	Defense Services Hospital
	Mandalay	Mandalay General Hospital
	North Okalapa	North Okalapa General Hospital
	Yangon	Yangon General Hospital

Appendix 1. continued

Country	City	Hospital name
Nepal	Dharan	B.P. Koirala Institute of Health Sciences
	Kathmandu	Medicare National Hospital and Research Centre
	Kathmandu	Nepal Medical College
	Kathmandu	Nepal Orthopaedic Hospital
	Janakpur	Orthopaedic and Trauma Clinic
	Kathmandu	Patan Hospital
	Banepa	Scheer Memorial Hospital
	Kathmandu	Tansen Hospital
Pakistan	Faisalabad	Allied Hospital
	Abbottabad	Ayub Medical College
	Larkana	Chandka Medical College Hospital
	Karachi	Civil Hospital Karachi
	Jallo More Lahore	Ghurki Trust Teaching Hospital
	Abbottabad	Gilani Hospital Complex
	Nawabshah	Nawabshah Medical College Hospital
	Islamabad	Pakistan Institute of Medical Sciences
Papua New Guinea	Port Moresby	Port Moresby General Hospital
Philippines	Bacolod	Corason Locsin Montelibano Memorial Regional Hospital
	Davao	Davao Medical Center
	Ozamiz City	Mayor Hilarion A. Ramiro Regional Training and Teaching Hospital
	Manila	Philippine General Hospital
Russian Federation	Krasnoyarsk	Emergency Hospital Krasnoyarsk
	Abakan	Emergency Hospital of Abakan
Belarus	Minsk	Belarusian Scientific and Research Institute of Traumatology and Orthopaedics
Dominican Republic	Santo Domingo	Centro de Ortopedia y Especialidades
	Santo Domingo	Hospital Dario Contreras
	Santiago	Hospital Regional Universitario Jose Maria Cabral Y Baez
Guatemala	Guatemala City	Hospital General San Juan De Dios
	Quetzaltenango	Hospital Regional de Occidente San Juan de Dios
	Guatemala City	Roosevelt Hospital
Haiti	Deschappelles	Hospital Albert Schweitzer
	Cap-Haitien	Hospital Justinien Universitaire
	Port-au-Prince	Trinity Hospital
	Port-au-Prince	University Hospital
Honduras	San Pedro Sula	Catarina Rivas Hospital
Nicaragua	Rivas	Gaspar Garcia Lavinana
	Esteli	Hospital San Juan de Dios Esteli
	Leon	Rosales Hospital
Saint Lucia	Castries	Victoria Hospital
USA	Oakland	Operation Rainbow
Brazil	Santarem	Hospital Municipal de Santarem
Ecuador	Quito	Hospital Pablo Arturo Suarez

References

1. Beveridge M, Howard A. The burden of orthopaedic disease in developing countries. *J Bone Joint Surg Am.* 2004;86:1819–1822.
2. Ghaffar A, Hyder AA, Bishai D, Morrow RH. Interventions for control of road traffic injuries: review of effectiveness literature. *J Pak Med Assoc.* 2002;52:69–73.
3. Krug EG, Sharma GK, Lozano R. The global burden of injuries. *Am J Public Health.* 2000;90:523–526.

4. Mathers CD, Lopez AD, Murray CJ. The burden of disease and mortality by condition: data, methods, and results for 2001. In: Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJ, eds. *Global Burden of Disease and Risk Factors*. New York, NY: Oxford University Press; 2006:45–93.
5. Mock CN. Injuries in the developing world. *West J Med*. 2001;175:372–374.
6. Murray CJ, Lopez AD. The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries and risk factors in 1990 and projected to 2020 (Global burden of disease and injury series; vol. 1). Boston, MA: Harvard School of Public Health; 1996.
7. Peden M. Global collaboration on road traffic injury prevention. *Inj Contr Saf Promot*. 2005;12:85–91.
8. Peden MM, McGee K, Krug E. Injury: a leading cause of the global burden of disease, 2000. Geneva: WHO; 2002.