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Supply Chain Management Models to Improve the Impact of Orthopaedic Equipment Donations

A Thesis Submitted to the
Yale University School of Medicine
In Partial Fulfillment of the Requirements for the
Degree of Doctor of Medicine

By

Youssra Marjoui

2011

SUPPLY CHAIN MANAGEMENT MODELS TO IMPROVE THE IMPACT OF ORTHOPAEDIC EQUIPMENT DONATIONS. Youssra Marjoua. Section of Health Policy/Political and Economic Development, Harvard Kennedy School of Government, Boston, MA. (Sponsored by Seth Dodds, Department of Orthopaedics, Yale School of Medicine).

Abstract

More than any other surgical subspecialty, orthopaedic surgery relies heavily on the use of implants and instruments, particularly in the provision of trauma related orthopaedic injuries, which are increasingly prevalent in low-income countries (LICs). The current international response to improving musculoskeletal care in LICs, is primarily geared towards increasing the donation of supplies used in orthopaedic surgical procedures.

This study outlines the current response, and assesses the supply chain component of international aid efforts to improve fracture care. It then explores this component with a goal of determining how a sustainable source of functional implants can be delivered to skilled surgeons, to maximize the synergy of appropriate training and proper equipment towards delivering safe, simple and cost effective orthopaedic care in resource poor settings. There are two hypotheses: The first claims that the creation of a 'coordinating unit' authorized to manage the supply donation process and the stakeholders involved, will improve the delivery of musculoskeletal care in LICs. The second claims that the implementation of a virtual and physical supply chain platform will improve the delivery of musculoskeletal care in LICs. The hypotheses propose that a correlation exists between optimization of the donation process and the achievement of improved delivery of musculoskeletal care. The research methodology is qualitative, consisting of interviews and observations, field research, literature reviews and case studies. Study findings reveal that conducting local needs assessments, helping recipients identify and

communicate demands, and confirming the presence of adequate local infrastructure and workforce capacity to receive and utilize donated equipment, are essential steps that should be executed prior to the deployment of donations, both within disaster and non-disaster contexts. In addition findings indicate that investment in logistical platforms and supply chains to manage donations, and establishment of a central coordinating unit to link stakeholders and information exchange, are highly instrumental in optimizing the provision of supplies and thus the delivery of orthopaedic care. The study results support the hypothesis that a 'coordinating unit' can provide a standard approach towards assessing need, capacity, and resource inventory, and can coordinate stakeholders in a manner that maximizes the use of individual and corporate donations, and supports the surgical capabilities of surgeons and healthcare workers delivering musculoskeletal care in LICs.

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Chapter One: Introduction

Background of Problem

The pairing of rapidly evolving technological healthcare innovations in high-income nations, and the rising opportunities to transport such equipment and services to resource constrained settings, has set a stage for more promising opportunities and more penetrating questions. As it stands, the growing impact of globalization specific to the provision of healthcare, matched with the unprecedented rise in philanthropic service by organizations and well-intentioned providers, have rendered many developing countries reliant on international donor aid to support the provision of basic healthcare services. Donor assistance is inclusive of a wide range of services, medicines, and healthcare delivery tools. Specific to the device-dependent practice of orthopaedics, this assistance is predominantly composed of donations in the form of instruments and implantable hardware, as well as larger imaging and sterilizing equipment. It is the case that due to inadequate funding, hospitals in low-income countries lack the instrumentation necessary to surgically repair severely fractured bones. Patients must purchase their own surgical implants, and since they are often unable to afford the cost, they are forced to remain in traction for months or years with poor treatment outcomes and adverse economic repercussions for them and their families.¹ This conundrum has led some nations to acquire approximately 80% of healthcare equipment (including orthopaedic implants and instruments which may or may not be appropriate for use in the local setting) through the charity efforts of international donors.²

This statistic reveals a drastic level of dependency, portrays a very generous transfer of resources, and masks the haphazard process, which often renders orthopaedic supply

donations ineffective. While a laudable service by the international community, the assistance offered by charitable donors in the orthopaedic community also calls for careful review. Consideration must be given to the multidimensional resources necessary for supporting the management and utilization of donated goods, and for preventing equipment from sitting idle. The absence of this consideration is partially due to the scarcity of resources that support administrative systems, staff, user-training and technical support, supply chains and the logistical support structures to facilitate the use of equipment. These organizational, financial and human resources are necessary to ensure that donations meet the needs they intend to serve, without causing a burdensome unloading of unusable equipment, and a further weakening of fragile healthcare systems in resource poor countries.

The Challenge

The existing process of providing aid in the form of donated supplies certainly stands to gain from adjustments that could improve the impact on healthcare delivery, while also benefiting the donors and recipients involved. A key intercession to ensure that health care equipment donations are optimized is to consider them in the context of country-specific donation and healthcare delivery processes. At present, the provision of access to previously unavailable equipment is approached as a task tangential to the local delivery of health care. More specifically, donor aid in the form of healthcare equipment is managed as a service detached from the practical delivery of patient care.³ As a result, the operationalization and implementation of this equipment to produce a positive impact do not receive adequate attention from health care planners and donors alike. This is the case despite the fact that these issues underlie donation decision-making processes, and

should be points of concern for donors, recipients and policymakers. It is also the case because the present global business environment with increasingly complex channels of inventory, supply, demand and distribution, renders the creation of synchronized humanitarian supply chains for low-income countries much more difficult. It also renders the prioritization of the process much more crucial to achieving appropriate donations procedures. With few exceptions, the overwhelming response to the rise of musculoskeletal disease burden world-wide has been an increase in donated supplies without consideration for the appropriate use of these supplies, the unique needs and limitations of each recipient facility, nor the necessary support and training that should accompany their provision. The challenge addressed in this research is of determining how to improve this existing system of assistance towards providing musculoskeletal care, with the provision of a more targeted, accountable and comprehensive system that addresses the existing deficiencies.

Key challenges found to accompany the sustainable and effective provision of medical equipment donations have been researched in models of pharmaceutical drug supply chains for HIV treatment as well as retail sector distribution chains for malaria treatment in the developing world. These challenges included difficulties with inventory management, procurement, quantification, forecasting and communication of needs.⁴

However the presently marginalized *process* of donating equipment relative to the well-intentioned though ineffectively organized *act* of giving, will likely be gaining a growing priority in the field of humanitarian aid. This can partially be attributed to improvements in global communications and thus a growing awareness of the successes and failures of

donation efforts. It can also be attributed to the deployment of humanitarian aid during several recent disaster response efforts, which have highlighted repeated weaknesses in the application of donor aid (Lewis Zirkle MD, Christopher Born MD, Personal Communication February 2010). Furthermore as the growth in technical innovation rapidly drives the standard of care to unprecedented levels in high-income countries, the evidence of scant resources and sub-standard equipment in low-income countries becomes much more pronounced.

From an orthopaedic perspective, the considerable shortage of necessary equipment in developing countries has been shown to greatly prevent the local delivery of appropriate musculoskeletal care.⁵ In turn, the transfer of orthopaedic equipment has become a natural focus for recipients and a significant value-creating opportunity for donors. The issue however, is that while many individuals and groups with meritorious intentions have become involved in this service, they do so without a sustainable system that successfully links the transfer of orthopaedic supplies from the donors (i.e. small scale clinics and hospitals or corporate suppliers), to the recipient surgeons and hospitals in low-income countries. The development of such a system, which introduces formal consideration for local resource and training capacity, will be the focus of several chapters to follow.

It is also the case that the proximity and orthopaedic-based nature of the tragic earthquake in Haiti one year ago led to a surge in orthopaedic-specific donation efforts. While certainly not the first record of the need and provision of orthopaedic treatment in a challenging disaster response setting, this particular event by virtue of its proximity and scale, highlighted the current process of donating orthopaedic supplies, and uncovered

existing deficiencies in the system. The value and advantage of charitable orthopaedic equipment donations, as well as the causes and potential solutions to donation process deficiencies will be the foci of questions addressed through this thesis research.

Chapter Two: Research Questions and Methods

Research Questions

More than any other surgical subspecialty, supplies, instruments and implants are fundamental to the practice of orthopaedics, in turn and accordingly, supply chains are vital to equipping the delivery systems of orthopaedics.

The question of how do donors, recipients and policymakers create a supply chain management system that considers the capacity and resource limitations of the receiving facilities, and that most effectively equips surgeons in resource poor settings to deliver surgical care, both within disaster and non-disaster contexts, will be the focus of this research.

This research does not seek to make the case that the provision of orthopaedic supplies in resource poor countries would be the solution to inadequate musculoskeletal care in these settings. It instead acknowledges the existing trend of supply donations as a response to orthopaedic needs in resource poor settings and seeks to suggest a more accountable and effective method of providing such supplies when needed.

The goal will be to model an orthopaedic supply chain management system for the humanitarian sector, to serve orthopaedic supply needs during disaster response orthopaedics, and in the sustainable provision of musculoskeletal care in resource poor settings.

The research questions to assess and develop a framework for suggestions include the

following:

- How do the many actors involved in disaster relief, particularly nonprofit agencies and corporate organizations, manage the multiple, often uncoordinated and duplicated actions that emerge during disaster response efforts?
- What are the deficiencies present in existing orthopaedic device donation practices?
- Could the donation of orthopaedic supplies negatively contribute to the delivery of musculoskeletal care in resource poor settings? If so, how?
- Should organizations utilize virtually organized logistics platform to improve the accountability and appropriateness of orthopaedic supplies provided? And if so how do organizations best ensure the success of virtually organized logistics platforms?
- Would the creation of a ‘Coordinating Unit’ that would be tasked with the management of the supply chain systems and the coordination of the multiple stakeholders involved, improve donation practices and result in associated improvements in the delivery of care?

Hypotheses

There are two main hypotheses of the study. The first hypothesis claims that the creation of a ‘coordinating unit’ authorized to manage the process of orthopaedic donations and to coordinate all the stakeholders involved, will improve the delivery of musculoskeletal care in low-income countries. This hypothesis proposes that there is a correlation between optimizing the process of orthopaedic donations by donors and achieving more adequate delivery of musculoskeletal care in these resource poor settings. The second hypothesis claims that implementation of a virtual and physical inventory and supply

chain platform will improve the delivery of musculoskeletal care in low-income countries. This hypothesis proposes that there is a correlation between the optimization of existing orthopaedic supply delivery systems and the achievement of more adequate delivery of musculoskeletal care in these resource poor settings. The acceptance or rejection of the hypotheses, will allow for predictions on the optimal delivery models to improve the impact of orthopaedic equipment donations on the musculoskeletal care received in resource poor settings.

Research Methods

The research methodology informing this study is qualitative, with emphasis on outlining the underlying definitions of supply chain management, as well as their applicability to orthopaedic needs in the humanitarian sector. The qualitative method will allow for the consideration, assessment and analysis of the alternative approaches to managing logistics and supply chains for orthopaedic devices delivered to resource poor settings. The instruments applied include interviews and observations, field research, literature reviews and case studies that allow for comparing different models and extrapolating strategies applicable to orthopaedics

Interviews and Observations

The gathering of information to inform the recommendations outlined in this research, which are geared to improve the capacity of surgeons (orthopedic surgeons) in developing countries, was conducted through face-to-face semi structured interviews. These included interviews with surgeons, company orthopaedic device representatives (industry partners) and the non-profit receiving organization leaders. The interviews also

allowed for access to up-to-date data, to expert opinions on the topic of medical device supply chains and to the perspectives of stakeholders and contributors from different backgrounds (medical, military, humanitarian etc). The following individuals were interviewed:

Dheera Ananthakrishnan MD, ORTHOPAEDIC LINK

Christopher Born MD, Orthopaedic Trauma Association

Anne McCormick, Partners in Health

George Dyer MD, Brigham and Women's Hospital

Lewis Zirkle MD, Surgical Implant Generation Network (SIGN)

Jay Stanka, Stryker Trauma Sales Representative

Richard Gosselin MD, Institute of Global Orthopaedics and Trauma (IGOT)-UCSF

Lieutenant Colonel Jeffrey Dean MD

Hans Larsen MD, Haitian Society of Orthopaedics and Traumatology

This research has also benefited from the author's first-hand observations of orthopaedic supply chain management in a post-disaster setting in Port-au-Prince, Haiti (March 2010). The assessments referenced in the study were made during a two week volunteer trip to deliver orthopaedic surgical care in Port-au-Prince, Haiti with a team of orthopaedic surgeons, anesthesiologists, and nurses formed under the non-profit organization "Operation Rainbow". The observations recorded have allowed for assessment of the potential approaches to streamline the delivery of orthopaedic supplies in disaster settings. The combination of the methods above has been supplemented by a synthesis and organization of the literature reviewed, both to maximize the lessons

learned and to inform the strategies created.

Literature Reviews

A thorough analysis of research reports and findings was significantly relied upon for the development of strategies to address the research questions posed. Potential strategies were extrapolated from the literature and then further considered for feasibility and applicability. The literature accessed, in the form of journal articles and reports, was used to create a theoretical framework for potential strategies, to focus on the themes relevant the questions posed, and to reject or accept the interventions being considered.

Case Studies

Case studies, in the form of models applied by existing organizations were instrumental in conjuring up potential strategies and recommendations.

Chapter Three: The Orthopaedic Supply Chain and Existing Donation Practices

The Orthopaedic Supply Chain in High Income Countries

The delivery of orthopaedic surgical care in high-income countries has become inextricably tied to the adoption and use of advanced and evolving orthopaedic device technologies. Access to this innovative equipment has made the treatment of complex musculoskeletal conditions and catastrophic injuries more achievable, and to a much greater degree than ever before.

The medical device industry has globally become one of the fastest growing industries worldwide. To remain competitive in the field, orthopaedic device manufacturers substantially invest in research and development efforts that drive the innovation of

improved and more sophisticated products. While this sustained goal of innovation is intended to promote improved patient outcomes, it is often the case that the capacity to adopt new technologies in orthopaedics falls behind the pace at which these technologies are created and made available on the market.⁶ This is paired with the fact that the orthopaedic device supply chain is among the most unique of medical equipment distribution systems. Orthopaedic products include artificial hips and knees for joint replacement procedures, plates, screws and rods for trauma cases, and instruments and devices for spine procedures. The products are generally supplied through a 'consignment stock', or via a 'loan set arrangement'.⁷ In the 'consignment stock' model, an assortment of orthopaedic implants and supplies are stored at the hospital (either in the operating room or the central sterile supply department), and are owned by the manufacturing company until they are utilized. Once products are used during a surgical procedure, they are billed to the hospital, invoiced by the company representative and replenished in accordance with the hospital's inventory report. In the 'loan set arrangement' business model, the surgeon reserves a loan set with the hospital for a specific case. The set would typically include a complete series of sterile implants, with all sizes available, would also include templates for sizing during the procedure, the components necessary to fix the implant (i.e. screws), as well as all instruments necessary to perform the procedure. From this 'loan set' the surgeon would use the implant specific for the patient, would perform the procedure, and then return the 'loan set' to the hospital. The hospital then ships the 'loan set' back to the manufacturer for replacement and restocking.

It is plausible to imagine that with the sustained and rapid development of new

orthopaedic devices, much of what is loaned or consigned may remain unused and instead replaced with newly manufactured products (Dheera Ananthkrishnan MD, Personal Communication, December 2009). As such, U.S. manufacturers are often left with a large surplus of devices, which collect from first and second-generation designs, odd-sized implants, hospital returns, and miscalculated forecasting. This surplus, which typically sits idle, represents a significant resource sink for the manufacturer, in terms of warehouse space and tax burden. Much of this inventory is stored, lost or stolen and represents an underutilized resource. As such, it also represents a consistent and continuously replenished supply source that is used for distributing donations to resource poor settings. However, it is often the case that the process of providing supplies for use in the delivery of musculoskeletal care within resource poor settings, does not account for the differences in need and capacity between high income and low income countries. As this research aims to confirm, any alternative systems for the donation of such supplies must consider these differences and create systems that fully capture them.

Differences in Orthopaedic Needs and Services in High-Income versus Low-Income Countries

There is a substantial difference between the nature and treatment of orthopaedic conditions in high and low income countries. The robust and well-resourced health care systems of developed countries have enabled the timely and appropriate diagnosis and treatment of fractures, dislocations and other musculoskeletal conditions. In contrast, developing countries often contain a wide range of facilities established to cater to different segments of the population, from very modern facilities in city centers, to district hospitals with orthopaedic surgeons but no infrastructure to deliver care, or

villages with no facilities in close proximity. It is also the case that injury mortality rates are substantially higher in low-income countries when compared with high-income nations, a trend that is partially explained by a rise in the incidence of traumatic musculoskeletal injury accompanying urbanization and the use of motorized transport.⁸ These characteristics combined with the general presence of inadequate resources, and a limited cadre of health care personnel, have resulted in a high incidence of improperly treated or neglected and completely untreated fractures.⁹ The injuries and sequelae observed range from cases of infected non-unions that result from the performance of open reduction internal fixation procedures in sub-optimally sterile conditions with non-standardized implants, to cases where the long term sequelae of non-traumatic pathologies due to a lack of training and supplies, are not longer treatable. These are typically pathologies that rarely exist in developed countries (i.e. osteoarticular TB), but have never gone into remission in developing nations.¹⁰ The differences in conditions and resource availabilities underscore the need for appropriate attention to be paid to the types of supplies donated, and to uniqueness of the facilities chosen with respect to available surgical personnel, resources and infrastructure, as these elements will determine the outcomes associated with the delivery of care.

As was observed in Haiti following the 2010 earthquake¹¹, orthopaedic equipment suited for use in the U.S. does not translate to appropriate use in a setting with extremely deficient resources, and limited access to essential elements from antibiotics to clean operating room space and sterile technique. In order to achieve a more accurate and locally appropriate response to musculoskeletal needs in resource poor settings, this

research seeks to propose a method for improving the present donation system, which is characterized by an absence of demand assessment and concordant supply needs.

Understanding Current Donation Practices in Orthopaedics

Orthopaedic surgeons in low-income countries are bridled by the limited availability of orthopaedic implants and supplies. The care they provide is therefore often deficient and of limited effectiveness. The predominant channel of access to modern orthopaedic supplies for these nations is through the informal and formal donation programs conducted by orthopaedic supply manufacturers in high-income countries.¹² These donations programs are driven by manufacturing companies' good will, their access to tax benefits for donation of implants, the associated decrease in surplus inventory and cost of storing space, the fulfillment of corporate social responsibility and the enhancement of public relations. This effectively leads to the provision of donor driven aid, which does not adequately account for the needs and limitations of receiving facilities in developing nations.

In addition to industry donations, developing country hospitals, surgeons and healthcare non-profit organizations also receive donations from private hospitals, clinics and surgeons in high income nations, who are driven both by good intentions as well as an interest in off-loading their surplus goods. Added to this list are individual orthopaedic surgeons interested in volunteering and in need of supplies. For these humanitarian volunteer surgeons, the process generally entails direct contact with their supply company representatives with enumeration of the specific equipment needed, the amount required and the location where it will be sent. While this system eventually equips the surgeon with the equipment he/she needs to deliver care, it has been reported to be inefficient, ill-

adapted for use in receiving settings, non-capacity building and unsustainable.¹³ It is certainly the case that both donors and recipients can substantially benefit from the provision of orthopaedic supply donations. Large and small-scale donors stand to reap benefits in the form of fulfilling corporate social responsibility, achieving a decrease in inventory surplus with an associated increase in storage space, as well as additional tax benefits. Recipients certainly stand to benefit from improvements in the delivery of musculoskeletal care, in patient's functional outcomes, in improved hospital surgical capacity to treat a larger segment of the patient population, and associated increases in training opportunities for surgeons at these hospitals. However the achievement of such benefits presumes that donated materials are effectively delivered to the intended recipients, and furthermore presumes that once delivered, these materials would be effectively used to result in the intended benefits.

For all of the charity donation mechanisms mentioned above, there exists a haphazard nature to the processes employed. There are several impediments that often remain unanticipated, unrecognized and unaddressed by donors, which include the inspections and frequent subsequent mishandlings at airport customs clearances, at the local government level and even within hospital and clinic quarters. The low prioritization of accurately documenting supplies received, used and stored also further decreases the capacity to ensure that products reach the operating room, and render it virtually impossible to produce reliable inventory systems at recipient sites. Even the supplies that traverse pre-hospital obstacles to delivery may still be bottlenecked by the failed logistics of distribution systems in recipient countries, (which often steer high cost complex items to be distributed to hospitals that lack the capacity to utilize them). For the most part,

donor based policies have governed the supply procurement process; often taking limited consideration of recipient country systems, (whether equipped with loose procurement channels or informal networks). As a result the significant logistic drawbacks and limited infrastructure present in low and middle income countries, continue to impede the appropriate receipt, delivery and use of donated supplies, and continue to result in failure to deliver services to the populations intended. This expectedly perpetuates the debilitating reliance that local hospitals and humanitarian organizations have on the unpredictable supply, which is received from donors. It also contributes to the lack of capacity to absorb the supplies received, and the lack of logistic systems to identify what exists, what is needed, and from whom to request it.

It is also the case that the low consideration given to assessing local capacity, product requirements, technical expertise and the availability of staff to receive and distribute orthopaedic equipment, leads the current system to function as a very expensive channel for equipment to be moved from warehouses in the U.S. only to lay idle in storage spaces overseas. Moreover, these are often storage spaces that are grossly disorganized and not equipped with the inventory systems to manage supplies. To begin to rectify this impaired system, the workflow process for successful delivery of resources to the target site needs to be carefully diagrammed, detailed and choreographed for the multiple stakeholders involved. Otherwise the risk of providing equipment that cannot be received, delivered to the operating room, properly used, maintained or repaired, will quickly become more of a liability than an asset. These issues raise questions for the need for donor and recipient guidelines.

Chapter Four: Exploring the Need for Medical Equipment Donation Guidelines

Rationale for the Need of Donor Aid Guidelines

The justifications for the need of guidelines for orthopaedic device and instrument donations are many, and consistent with the themes mentioned thus far. It is the case that while manufacturers, organizations and individuals on the donor end are organized, logistically prepared and well-intentioned, they often dismiss or remain oblivious to the multiple layers of logistical challenges and unpredictable events on the recipient end. This disconnect while driven by practical and systemic challenges, is also a product of ineffective communication and asymmetric decision-making power. Recipients are rarely afforded the opportunity to specify their needs, nor do they have the support to adequately communicate them. In addition, donor assumptions that recipients will have the technological, administrative and human resource capacity to receive and utilize donated equipment, can lead to haphazardly distributed goods that are not selected based on sound analysis, and as a result do not effectively meet the resource necessities of target sites.

Unique and of particular relevance to orthopaedics, are the steps required to monitor the quality and integrity of complex implant sets, and the extra attention needed to ensure the provision of basic operational support systems. These systems include the manuals and tools, which accompany instrument sets, as well as the more detailed considerations of language of instructions, country-specific voltage as well as the availability of supplementary equipment such as C-arms, fracture tables and autoclaves. This manifold nature of appropriate orthopaedic donations warrants the need for guideline development,

as well as the need for implementation strategies to improve the process, quality and impact of donated orthopaedic equipment.

The World Health Organization (WHO) Donor Guidelines

In 2000 the World Health Organization (WHO) developed general guidelines to drive the process and content of health care equipment donations geared towards low and middle-income countries.¹⁴ While generic in design, the guidelines could reasonably be adapted to fulfill orthopaedic equipment donations. They could be applied to systematically consider all critical parameters, and to work towards fulfilling targeted objectives without creating added burden to the fragile infrastructures of recipient programs.

Core principles of WHO guidelines for equipment donations¹⁵

According to the WHO guidelines, the core principles directing donor guidelines should include the following:

- 1) Health equipment donations should function to benefit recipients to the maximum degree possible.
- 2) Donations should be provided with full consideration of the preferences and authority of recipients, and in compliance and accord with the policies and administrative systems of recipient countries.
- 3) The standards of quality of equipment sent should mirror donor country standards.
- 4) There should be balanced communication between donor and recipient, with plans co-formulated by both parties.

Correspondingly, the core principles directing recipient guidelines on health care equipment donations should include the following:

- 1) Defining guidelines for health care equipment donations specific to the receiving country or organization, including the selection, quality and management of donations.
- 2) Outlining specific administrative procedures, enumerated roles and outlined responsibilities for receiving equipment donations.
- 3) Defining itemized needs for donated health care equipment.
- 4) Identifying a lead donor.

Elements to Consider in the Implementation of Guidelines

For musculoskeletal injuries associated with disasters or accidents, the availability of basic surgical supplies and instruments are essential, as care cannot be otherwise provided. While it is certainly the case that many disasters are impossible to predict with accuracy, the basic equipment necessary for Damage Control Orthopaedics (DCO) (i.e. immediate external fracture fixation), can be predicted and standardized. Systematizing the process through preparation will allow for improved accuracy and rapidity of response, as well as the space and capacity for replenishing and supplementing supplies as needed.

Towards achieving standardization, the WHO in concert with UNDP/IAPSO, UNHCR, UNICEF, UNFPA, ICRC, IFRC and MSF produced a compendium of 'Emergency Relief Items', with the goal of defining the supplies necessary during the immediate response phase in order to facilitate procurement and delivery. The standardized surgical supplies related to orthopaedic care, fall into the categories of sterilization, surgical instruments, sutures and surgical needles, anesthesia material and X-ray material. The WHO has also

issued specific guidelines for donations of used and refurbished equipment, which call for the restoration of equipment to original manufacturer specifications, and the subjection of this equipment to principles of liability.

Steps to Incentivize the Adoption of Guidelines

Despite the availability of thorough guidelines, process standards, stakeholder specific checklists and responsibility assignments, there still remains a gap in the adoption and application of these instruments in the provision of donated goods. For several reasons the process remains largely unchanged, has failed to appropriately deliver donations, and has effectively limited the impact produced. The following sections will explore the current systems of delivering medical equipment, and orthopaedic supplies in particular, in the context of disaster response.

Chapter Five: Current System of Orthopaedic Donations Towards Disaster Relief

The systems of orthopaedic donor assistance and the challenges that accompany them in stable settings have been outlined above. The discussion of donations in disaster relief settings will capture many of the same principles, including severely inadequate utilities, absent needs analyses, unequal distribution systems, limited technological capacity and insufficient quality assessment processes. However, attempts to deliver donations during disaster are further complicated by several factors. These factors involve the development of leadership chaos, with unclear, fragmented and at times adversarial efforts to lead among many contributors and stakeholders. These stakeholders include community based organizations, local government offices, national government offices, national and international nonprofit aid organizations, volunteering individuals and

groups, volunteering businesses – such as CARE, OXFAM or Coca Cola, as well as the offices of United Nations—such as the Office for the Coordination of Humanitarian Affairs (OCHA) or UNICEF. These siloed branches of aid also then suffer from miscommunications, which foster duplication and prevent the interactions necessary for achieving a coordinated response.¹⁶

Complicating this chaos is the acute rise in demand experienced during disaster, coupled with the general lack of immediate access to sufficient basic supplies. In addition, the significant difficulties in identifying, quantifying and forecasting burdens of injury and equipment needs further confound the ability to respond. The confusion of disaster response is also often exacerbated by the weakened and decimated healthcare delivery systems of the countries affected. The limits of technological capacity in impacted nations, and the absence of investment in logistical platforms to coordinate aid, result in the dreaded inappropriate influx and unequal distribution of aid that compromises acute disaster response.

Inappropriate Influx and Unequal distribution of aid

In the absence of a shared needs assessment survey or a coordinated response plan, the distribution of aid becomes dependent upon proximity to the source of delivery. This includes proximity of access to nearby roads, media coverage, and circulating aid workers.¹⁷ These incomplete methods of assessment inevitably perpetuate a duplication of efforts, and compromise treatment access to a large percentage of victims who haphazardly happen to inhabit the wrong route. More importantly for orthopaedics, this method of distribution is completely impractical, inaccurate and infeasible for determining the burden of injury and identifying specific equipment needs.

In Port-au-Prince, Haiti the influx of inappropriate equipment interspersed with requested and necessary supplies, created the bottlenecks that overwhelmed the capacity of the government to process and clear the shipment of goods. While this was certainly associated with the absence of appropriate customs laws, regulations and logistical systems on the recipient side, it was also created by an overstock of donated yet often poorly targeted supplies. Even the efforts of the U.S. military could not fully build the capacity to clear the gridlock created by the influx of inappropriate and unnecessary donations.¹⁸

Chapter 6: First Hypothesis— *Creation of a ‘coordinating unit’ authorized to manage and coordinate the process of orthopaedic donations*

The first hypothesis claims that the creation of a ‘coordinating unit’ authorized to manage the process of orthopaedic donations and to coordinate all the stakeholders involved, will improve the delivery of musculoskeletal care in low-income countries. This hypothesis proposes that there is a correlation between optimizing the process of orthopaedic donations by donors and achieving a more adequate delivery of musculoskeletal care in resource poor settings. To test this hypothesis a comparison will be carried out between existing models of orthopaedic donation efforts (during disaster and non-disaster response), and proposed models of “coordination units” applied towards donations in other medical fields. The outcomes of the comparison will be used to form predictions on the feasibility and applicability of “coordination unit” models in providing improved musculoskeletal care in resource poor settings. The comparison will begin with (i) a review of the stakeholders involved in the activation of an emergency medical supply chain during disaster response (with lessons extrapolated to non-disaster settings),

followed by (ii) a review of the challenges unique to the provision of supplies necessary for musculoskeletal care in disaster response and the logistics systems necessary for delivering it, (iii) an outline of models used for coordinating the delivery of orthopaedic and non-orthopaedic supplies, and will then introduce the concept of a “coordinating unit” and test its applicability in improving the delivery of orthopaedic care through optimizing the coordination of donation practices during disaster and non-disaster settings.

Stakeholders Capable of Advancing or Interfering with Coordination of Response

A review of the literature detailing the participants involved in the activation of an emergency supply chain reveals a re-occurring presence of seven networks.¹⁹ These include the recipient country(s), neighboring nations, military support, donors, suppliers, implementing partners and the media.

Impacted Country

The country impacted by disaster serves as the first link of the relief chain. To assure the participation of the international community, the impacted country is expected to explicitly welcome rescue and relief efforts from other governments and humanitarian organizations. Expectedly, the immediacy with which a nation declares a request for help certainly enables a more rapid launch of the humanitarian emergency relief supply chain. In the setting of decimated resources, infrastructure and non-existing logistics assets, as is generally the case in low and middle-income nations impacted by disaster, it becomes the responsibility of the assisting humanitarian organizations to create the logistic and supply chain management systems necessary for an effective response.

Neighboring Nations

As the recent earthquake in Haiti revealed, the contributions of neighboring nations are crucial in the planning and implementation of a timely response. Neighboring countries played a role in expanding the operational options available to the organizations involved in delivering resources for relief. Neighboring country infrastructure, (physical and operational), for emergency and disaster relief is therefore necessary for securing, delivering and storing supplies as well as mobilizing humanitarian staff. Effectively the accuracy, timeliness and cost-effectiveness of these efforts largely depend on the systems used by nearby donor nations. Whether through government agencies, nonprofit organizations, private entities or public-private partnerships, the response to disaster would be most likely be optimized through a combination of the unique and complementary assets of each agency.

Military Forces

Reviews of the vast contributions provided through military support reveal that the military generally assumes three roles during emergency relief.²⁰ Military personnel primarily establish security, surveillance, and maintain order, while also being present to provide ongoing protection. The military is remarkably equipped to provide logistical support, as well as critical equipment and supplies to humanitarian organizations positioned to deliver relief. They also provide direct assistance towards medical evaluation and treatment, support for transportation and delivery, and supplementation of the efforts of humanitarian organizations. In relation to the contributions that a ‘coordinating unit’ can make to the provision of orthopaedic supplies in a disaster setting, a focus may be placed on the military’s instrumental role as a provider of logistical

teaching and support.

By virtue of the military's structure and function, it has necessarily built robust logistics systems and resources. The force's expertise in responding to urgent needs with well-coordinated delivery efforts, lends an incredible resource that could be harnessed by humanitarian organizations. Similarly, access to available military resources at internationally positioned distribution centers, and to the rapid, precise and flexible distribution channels they control through controlled transportation by air, land and sea also augment the response capacity and timeliness of humanitarian organizations which have access to these resources.

However while civilian-military partnerships would significantly improve disaster response efforts, there are several factors that impede coordination and collaboration between the two actors.²¹ These factors include differences in organizational structures and leadership architecture, differences in communication procedures, and in ideological and cultural norms. They also include efforts by humanitarian organizations to maintain impartiality and to refuse the potential association with the use of force correlated with the military, leading them to guard and constrain their interactions with the organized body of armed forces. While challenging, these impedances are surmountable and call for a range of strategies to build improved communication, consultation processes and cooperation towards a common goal.

Donors

An adequate relief response to large-scale disaster in a resource-constrained nation generally relies on donor support, from governments, businesses, humanitarian agencies and individuals. It also usually arrives in the form of monetary funds, volunteer

personnel, and service delivery support. This renders donors able to assume a variety of positions—as monetary donors, as suppliers of specific goods or as providers of logistics expertise and assistance. However, what is particularly more pertinent to effective relief efforts for orthopaedic injuries, are the needs to assess and identify supply requirements, to secure complete instrument and implant sets and to deliver where the capacity for providing orthopaedic surgical care exists. This includes the technical capacity to perform the surgeries indicated with the supplies provided, the infrastructural capacity to operate the supplies and devices delivered (including electricity and water), as well as the availability of assistive devices typically relied upon in high-income countries (i.e. fluoroscopy), which may not be available and functioning in resource poor settings. The contributions of corporate donors consist of either monetary or product-specific gifts. When non-monetary, their input as suppliers of equipment is often driven by a push-allocation mechanism of giving unsolicited and unsuitable donations of surplus goods (Dheera Ananthakrishnan MD, Orthopaedic Link, Personal Communication, December 2009). With this baseline position, corporations have great opportunities to maximize their donation efforts through the sharing of technical expertise, through partnering with an orthopaedic supply-specific logistics provider for the delivery of humanitarian aid equipment, and through improving their coordination efforts through partnering.²²

Providers of Supplies

The limited resources of many hospitals and nonprofit humanitarian organizations in low-income countries, in addition to their fluctuating finances, and the unpredictability of the challenges and disasters they face, all curtail their capacity to pre-stock supplies. These challenges also limit the capacity to develop the inventory logistics systems necessary for

an effective local response to disasters (Lt. Colonel Jeffrey Dean MD, Personal Communication, 18 February 2010). This renders local organizations highly dependent on existing supplier networks for relief in the aftermath of disaster, albeit with an absent relationship between donors, recipients and the supply chain that links them. Specific to orthopaedics and orthopaedic-related disasters such as earthquakes, the collection and delivery of a large volume and range of orthopaedic supplies that are both standardized and injury/procedure specific, require a long-standing, committed and responsive network of industry partners. The presence of such a network would absolve the need for re-constructing a new disaster specific network of suppliers with each catastrophic event. It would also expand the number of suppliers contracted for equipment, and thus remove the losses and inefficiencies incurred in continuing to re-establish relations and processes between geographically dispersed suppliers and recipients.

Implementing Partners

Local nonprofits with wide ranging local networks, cultural knowledge and expertise and/or an exceptional track record of providing care in a disaster, renders them best positioned to be involved in the implementation phase of relief efforts. Effectively, it follows that partnerships between corporate donors and on the ground NGOs who can be supported to implement services, will invariably lead to greater success in increasing the accuracy, sustainability and speed of delivering care.²³ The value of these long-standing local networks is best displayed through the effective and efficient efforts of non-profit organizations Partners in Health and AmeriCares, during the Haiti earthquake response.²⁴

Media

The most essential element of disaster relief at all stages of response, recovery, mitigation

and preparedness is information. However while most valuable, information during these phases also tends to be the most incomplete, initially scant and continuously evolving. The recent quake in Haiti unequivocally displayed the influential role that the media, in the form of national and international news agencies, radio stations, journalists and photographers had in communicating live and streaming information during the most uncertain and difficult early phases of the crisis. As a result they naturally became the primary source of up-to-date information for organizations providing relief on the ground. For the global audience, it was the reported news of a tragic disaster that galvanized a response and set in motion a vast resource supply chain.²⁵ Social media as was remarkably displayed by the earthquake in Haiti, served as an invaluable tool for enabling everyone (both those on the ground and those observing from a distance), to report and receive live and up-to-the-minute information on disaster relief efforts. Social media networks and resources integrated with traditional reporting channels, allowed for maintaining an elevated level of urgency from the hours and days immediately following the quake. This comprehensive delivery of news coverage on relief was positively correlated with the level of channeled resources and support services, as well as the mobilization and distribution of goods. However this also led to the creation of discrepancy in access to resources. For the organizations receiving extensive coverage and acknowledgment by the media, the funding and donation efforts were plentiful and even beyond capacity, however for those organizations that garnered minimum media attention the resources became meager and limiting (Lewis Zirkle MD, Personal Communication, April 2010).

It is certainly the case that while the media certainly improves access to rapidly changing information, it also wields great power in shaping the public's view and in guiding the

investment of public resources through the choice of coverage of organization efforts and achievements. Specific to orthopaedics there is a need to provide a safety net for those organizations providing musculoskeletal care, and not able to garner enough media coverage to maintain an adequate stream of funding and resources.

Coordination Among Stakeholders During Temporary Involvement

A challenge within the structure of temporarily involved and loosely coordinated contributors, is the inevitable difficulty in choreographing the many efforts, and significantly varied levels of expertise present in their disaster relief work.²⁶ To begin to address these concerns, a spotlight needs to be placed on the logistics and supply chain management systems of health organizations within the disaster stricken countries and their neighboring nations. It also calls for a similar focus from medical supply providers and donors, who can play a role in neutralizing the asymmetric influences of the media by creating reliable systems to the process of giving.

Challenges Unique to the Provision of Musculoskeletal Care in Disaster Response

The previous sections have established that in low-income countries (LIC), musculoskeletal conditions often go untreated due to a lack of infrastructure, personnel and equipment. Many organizations have identified existing skill sets in developing countries, and are working to improve these with mission trips to provide teaching and direct care. The equipment used in mission trips is generally current generation non-surplus inventory, requires physician procurement, and is typically not suitable for use in the country of need, and not necessarily familiar to the local surgeons providing sustained care. In addition, corporations are expected to coordinate the multitude of donation

requests from individual surgeons, and the many non-governmental organizations (NGOs) that arrange surgical mission trips, a task that most corporations are not been equipped to carry out. Furthermore, the majority of individual donation requests are for high demand third-generation inventory, which often leave corporations with lost profit potential to follow their donation efforts.

Managing a supply chain for complex equipment in the setting of *disaster response* creates additional layers of difficulty. While many of the tools and lessons extrapolated from general and orthopaedic-specific donation models can be applied in creating a supply chain management system for disaster relief, they must be tailored to the context of catastrophic disaster and rapid response. They furthermore should be adapted to address the unique challenges that arise in executing appropriate action.

Humanitarian Relief Logistics and Supply Chain Management Overview

Role and Significance of Logistics for Humanitarian Relief

Logistics in this discussion will be defined as ‘the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary’s requirements’.²⁷ For the specific flow of resources that are of concern to orthopaedics, logistics can be defined as the systems and processes that underlie the mobilization of orthopaedic supplies in a quick and accurate manner to provide musculoskeletal care where needed, whether in response to disaster or in stable settings. Supply chain management in this context will be defined as the network of manufacturers, suppliers, distributors, retailers and customers, which supports

information, material and financial flows. Thus if appropriately designed, an effective supply chain in the humanitarian sector would have capacity to respond to the injuries of a large-scale disaster or to a chronically under-resourced facility, within a short period of time.²⁸

The limited resources and capacities of health facilities in low income countries often provide no opportunity to invest in a preparedness phase, leaving these local and most closely positioned organizations with insubstantial or absent logistics systems. Specific to disaster response, the unpredictability and occurrence of natural or man-made events in resource limited settings with limited funding, insufficient technology access, very basic and manual information systems, and inefficient internal processes, render the implementation of logistical procedures formidably difficult. They also expectedly lead NGOs to reactively respond to disaster without a logistical platform to rely on.²⁹

Consequently there are no mechanisms in place for collecting data, assessing needs and formulating appropriate response plans. As a result, there is poor coordination among agencies and a lowered prioritization of collaborative efforts, as these efforts become more difficult to manage and inefficient in the absence of information to share.³⁰ The lack of coordination and communication also exists between the donors and contributors to different segments of the supply chain, and further drives the inaccuracies and disproportional distribution of supplies. Several of the volunteer surgeons in Haiti described very limited organizational infrastructure within most organizations they volunteered with, and reported the need to bring their own supplies and to continue personally replenishing their stock, as the organizations' personnel were largely unable to identify the actors involved in their supply chain.

Examples of the Logistics of Emergency Relief Responses

The December 2004 Indian Ocean earthquake and subsequent tsunami that claimed over 220,000 lives in South Asia, was the first clear indication of the significant systemic flaws that directed large-scale disaster relief efforts. It may have marked a defining moment for the involvement of the business sector in disaster relief, and provided an opportunity to identify areas for improvement in organization and business sector responses. These included an improvement in the engagement and communication with local actors, and an increase in transparency and accountability towards the populations affected and the donors involved in contributing.³¹

The global response to the quake marked the largest donation effort in history at that point, totaling more than \$13 billion and largely led by the private sector as well as institutional and individual donors. Very similar to the response to the quake in Haiti, corporate executives sought to provide tangible resources rather than cash donations, and for orthopaedic needs in particular, companies wished to donate supplies, implants and instruments to support surgical care on the ground. However both in South Asia 2004 and in Haiti 2010, the capacities of international humanitarian organizations were limited, and there were no logistics information systems at the health centers and NGOs delivering surgical care. They were unprepared to perform needs assessments, unable to swiftly provide donors with lists of neither supply needs nor delivery locations, and unable to report back on the use and allocation of supplies delivered. In addition, there were no systems in place to rapidly communicate information on the changing supply requirements. This led to great difficulty in accurately replenishing supplies and determining if patient needs were being met with the items available. This is a level of

feedback that is necessary in ensuring a responsive, accurate and effective process of aid delivery.³² Thus due to both recipient and donor driven decisions, responses were largely uncoordinated and not based on needs assessments, resulting in excesses for some and shortages for others. In addition research has shown that corporations placed a significant focus on promoting agency brand, and invested in insufficient engagement with local actors.³³

With the exception of Partners in Health (PIH) in Haiti, it was also the case in both disasters that local on-the-ground organizations, which could have been immediately available to provide relief, were unable to utilize the resources sent as they were ill equipped to perform inventory evaluations, and unprepared to absorb the supplies donated. This outcome can be explained both by a shortage of staff as well as the absence of an organizational logistics system.

Both in 2004 and 2010, fragmented systems expectedly led to the delivery of unsolicited and often inappropriate items that congested warehouses. In Sri Lanka and Haiti, this led to the misuse of cargo space on flights that could have been more appropriately loaded with needed supplies, (and ultimately remained unclaimed at Sri Lanka's Colombo airport for months) for while many urgently needed supplies were delayed in reaching organizations delivering care.³⁴ However as previously mentioned, a small number of organizations were exemplary and effective in their relief efforts. Importantly they were effective secondary to the pre-established working relationships they had with relief organizations which helped to both guide their donations efforts, and to equip the relief agencies with resources and technical expertise.

Given the range of successes and failures of collaboration between corporations and

nonprofit organizations or relief agencies, the issue more important than the volume of aid delivered in response to crisis, is the recognition of a systems failure and the attempt to investigate and build more reliable donation structures and more productive partnerships.

For donors the business case could be made for greater focus and less non-targeted support for donation initiatives. Partnerships need not be formed at the expense of economic benefits, but can instead be aligned with a more efficient and cost-effective use of resources to create value and benefit for both the corporation and the beneficiaries in need.

Example of Ineffective yet Common Emergency Donation Practices

Interview reports of recent disasters reveal that the collection and allocation of orthopaedic supplies during disaster relief, have generally been fulfilled either by individual surgeons or individual organizations, with limited communication between the parties involved, and no preparatory plans in place for managing supplies and configuring logistics of distribution prior to disaster (Dheera Ananthkrishnan MD, George Dyer MD, Anne McCormick PIH, Personal Communication, March 2010). For example on January 20, 2010 Knowledge Ventures, a venture firm focused on the musculoskeletal industry, placed an online “Call for Orthopaedic Hardware for Haiti”.³⁵ This was advertised as a plea to orthopaedic surgeons, to seek their assistance in sending needed hardware to earthquake patients in Haiti. The organization forged an independent partnership with ORTHOWORLD Inc., a publishing firm focused on the business supply and strategy of orthopaedic supply chains in the global orthopaedic market. Specifically the venture firm called on “*all* orthopaedic professionals to identify *any* sources of hardware”, further

communicating that they have “arranged a public thread so that anyone can contact the appropriate agencies to get it delivered.” This effort is a prime example of commendable and aggressive intentions, which unfortunately lack appropriate forethought and strategy.

Effective Mechanisms for Coordinating the Delivery of Supplies

Reviewed below are several examples of coordination models for the provision of medical supplies, which will be considered in testing how the establishment of a ‘coordinating unit’ can facilitate the use of donated orthopaedic supplies to improve the treatment of musculoskeletal conditions.

Partnership for Quality Medical Donations (PQMD)

PQMD is an alliance of non-profit humanitarian organizations and manufacturers of medical equipment and pharmaceuticals working to meet health needs in developing countries.³⁶ PQMD is committed to improving medical donation standards, towards supporting cogent, high quality donation practices and communicating useful strategies to policy makers. While the Partnership’s mission is founded on conveying sustainable donation practices to those organizations involved in the management of medical donations, PQMD also works towards providing access to essential supplies in disaster response settings.

In producing a comprehensive strategy for medical supply donation management, PQMD builds upon the WHO Donation Principles and Guidelines. Their process always begins with a needs assessment. As applied to disaster response this includes an assessment of the nature of the disaster, a profile of the injuries sustained, the scale and the duration of the impact. It also includes a review of the demographics and socio-economic status of the population affected, as well as an assessment of the region’s location, climate,

accessibility and security. Lastly it includes an overview of the existing healthcare infrastructure and available human resources, as well as a brief investigation of government regulations on the import of donations, and a gauge of the local authority receptivity to foreign aid. PQMD secondly focuses on ensuring the appropriateness of donated products, in terms of meeting recipient needs as well as conforming to standard quality criteria. PQMD further outlines process steps for packaging and transportation, with costs born by donor organizations, and in accordance with country shipping policy. Their third point of focus includes ascertainment of the extent of human resources available in the recipient country, both for the reception of donations as well as the review and update process of existing inventory. Finally PQMD encourages the evaluation of donation practices to measure impact, and to utilize feedback towards making continuous improvements.

The consistent presence of PQMD alliance members in different countries under a standard set of donation practices, allows for immediate response to disaster. Their on-the-ground members and their partners are also prepared and equipped to make damage assessments, identify injury profiles and determine the type and level of aid appropriate to respond to either national disaster or local trauma needs in urbanized city centers.

MEDISEND³⁷

MediSend is a nonprofit, organization that supports low resource hospitals in developing countries. MediSend's mission includes the distribution of donated and surplus medical supplies for sustainable and emergency relief programs, and also includes the education, training and technical support needed to maximize the use of the donations. The organization partners with entities at different steps in the medical equipment supply

chain, including manufacturers, distributors and hospital systems. Then through its precise online Donor Asset Management System, it works to promptly supply specific equipment to qualified resource-poor hospitals that have worked to outline their itemized requests.

*Direct Relief International*³⁸

Direct Relief International functions to support manufacturers, distributors, and medical facilities towards donating healthcare equipment to hospitals and organizations overseas, in a consistent and accountable manner. The organization adheres to the WHO donation guidelines and is a member Partnership for Quality Medical Donations (PQMD).

Examples of Effective Orthopaedic-Specific Equipment Donation Models

*Surgical Implant Generation Network (SIGN)*³⁹

SIGN supports surgeons in resource poor settings worldwide in their treatment of victims of musculoskeletal trauma, whether due to events of disaster, the devastation of war or the rapidly rising incidence of road traffic accidents. Far beyond assisting in the training of orthopaedic surgeons, SIGN has developed the capacity to engineer the implants and instruments necessary for treating fractures in under-resourced settings. These are settings that typically lack dynamic imaging (i.e. C-arm fluoroscopy), and have limited access to electrical power. SIGN further developed a systematic donation process for delivering the instruments to over 200 programs worldwide. SIGN is unique in service not only through its orthopaedic focus, but also through its dual prioritization of instrument donation and local surgeon training.⁴⁰ SIGN sites are secured through a review of applications submitted by hospitals in resource poor countries, which are

equipped with surgical personnel but lacking the necessary equipment to operate. Once approved, equipment donations occur only once the surgeons have been trained, have displayed a capacity to practice the technique using the SIGN instruments and implants, and have committed to fulfilling the obligation to regularly report surgeries into the SIGN database. A very innovative and important tool, the SIGN database has been designed to track and evaluate the effectiveness of the SIGN system, and has gradually become a superb comprehensive forum for the discussion of questions, outcomes and innovative methods of care. The database is also used to determine the organization's manufacturing schedule, as SIGN automatically donates replacement supplies with every 20 surgeries reported, and thus determines its manufacturing supply load based on the database entries.

Partners In Health

Founded in 1987, Partners in Health (PIH) is a Boston-based non-profit organization with a mission to provide a "preferential option for the poor".⁴¹ The organization seeks to deliver modern health care to impoverished communities across the world, including Haiti, Peru, Russia, Rwanda, Lesotho, Malawi, Chiapas, Mexico and Guatemala. The organization seeks to provide diagnosis and treatment for patients free of charge, works to target and ameliorate the causes of disease in their communities including the economic and social burdens of poverty, and invests in disseminating lessons learned. PIH relies on instruments of service, training, advocacy and research to set a new standard for the delivery of care in resource poor settings.

Specific to providing access to medicines and supplies, PIH has established a well designed and substantially staffed system for procurement, management and distribution

of medicines and supplies to a network of multiple hospitals and clinics in different countries.

Central to this system are the following elements: (i) Assessment of the country-specific variables that impact purchasing decisions and logistics, (these include a local disease profile, investigation of the availability of warehousing systems and management personnel to analyze needs, personnel to solicit donations, plan and track shipments, manage the receipt, storage, management and distribution of supplies), (ii) Knowledge of the national regulations, importation laws and customs procedures for importing medicines and supplies, (iii) Analysis of the healthcare infrastructure, and (iv) Investment in a data management and inventory monitoring system.

For managing donations, PIH requires that supplies and medicines meet defined standards for quality, and be fully operational and electrically compatible where applicable.

Based on experience with an Electronic Medical Records (EMR) system for HIV patients, PIH developed a stock tracking system modeled on the standard WHO stock cards which allow for real time entry of stock levels, shipment tracking and requests.

PIH Response to the Earthquake, Port-au-Prince, Haiti

On the evening of January 12th, the PIH Boston-based procurement team began organizing emergency logistics operations, while maintaining constant communication with the team of physicians and nurses on the ground in Haiti. The team coordinated with large and small donors, the U.S. military, and government personnel to collect supplies and medicines. Concurrently they coordinated all shipments, custom clearances, and port

and airport deliveries with PIH staff positioned to unload and distribute planes full of equipment. The team also established a supplementary supply chain in the Dominican Republic. With access to stocks of supplies at PIH hospitals in regions surrounding Port-au-Prince, PIH worked to quadruple their annual surgical order to meet the orthopaedic and trauma needs that resulted from the earthquake. Then as the communication of needs became more systematized and reliable, the items sent became more specific and targeted. Simultaneously, the team secured warehouse space in Miami and Port-au-Prince, to prepare for the continued collection and systematic distribution that was anticipated in the coming months (Partners in Health Headquarters, Personal Communication, January 2010).

Orthopaedic Link

ORTHOPAEDIC LINK is a 501c3 US (GA) non-profit organization with a mission to serve as a link between orthopaedic implant manufacturers, and entities providing orthopaedic care in the developing world. ORTHOPAEDIC LINK'S objective is to mobilize idle surplus inventory from a consortium of orthopedic supply companies, to equip qualified surgeons in the developing world.

The proposed model utilizes a virtual distribution center to organize and allocate surplus inventory to prescreened recipient hospitals and organizations capable of delivering skilled orthopedic surgical care. Recipient assessments are to be carried out by a team of practicing orthopaedic surgeons, with high prioritization given to organizations characterized by local political stability, an existing hospital infrastructure, an existing orthopaedic skill set, an existing relationship with other NGOs, resident and nursing

training programs, and the presence of a nonprofit organization or government institution providing care to the indigent.

Using a supply chain management software program specifically designed for humanitarian efforts (Aid Matrix)⁴², ORTHOPAEDIC LINK would provide a system for managing, allocating and distributing available surplus inventory. The objective is for the organization to become a distribution center for a consortium of orthopaedic supply companies, creating an increase in the volume of orthopaedic equipment available to surgeons in the developing world.

ORTHOAEDIC LINK has two primary workflows: Donation Management and Surplus Inventory Allocation. Through these areas of focus the organization intends to provide suppliers with the knowledge, network and tools to coordinate, organize and allocate donation requests utilizing surplus inventory.

 *Donation Management:*

ORTHOAEDIC LINK'S comprehensive Donation Management solution is built on a supply chain platform specifically designed for humanitarian efforts. To take full advantage of product lifecycle, the organization focuses on priority allocation of surplus inventory (B and C level products) thus decreasing the distribution of current generation inventory (A level product) for humanitarian efforts.

 *Surplus Inventory Allocation:*

ORTHOAEDIC LINK'S Surplus Inventory Allocation process provides a controlled channel of distribution for idle inventory. Working in collaboration with NGO partners, ORTHOPAEDIC LINK would identify potential recipients for product donations in the developing world, and through a customized assessment tool would also identify each recipient's particular skill set and ability to use requested equipment.

Certified recipients gain access to ORTHOPAEDIC LINK'S virtual warehouse, which would allow online inventory visibility and the ability to request available surplus inventory. Once a request is submitted, ORTHOPAEDIC LINK resources review requests then submit the allocation request to the donating orthopaedic supply company. As with the Donation Management Process, the supplier (donor) manages the distribution and export documentation, and ORTHOPAEDIC LINK manages shipment tracking and recipient confirmation of receipts, by working with a third party warehouse and transport provider.

Applicability of a 'Coordinating Unit'

A Strategy for Humanitarian Supply Chain Management and Logistics

Based on the comparison of supply chain and delivery models that either emphasize the instrumental role of a coordinating entity, as with Partners in Health, SIGN, PQMD or ORTHOPAEDIC LINK, or neglect the need for such an entity, as displayed by several earthquake disaster responses and the independent efforts of private companies such as ORTHOWORLD, the assessment of proof for the first hypothesis will be considered.

The hypothesis holds that the creation of a 'coordinating unit' authorized to manage the process of orthopaedic donations and to coordinate all the stakeholders involved, will improve the delivery of musculoskeletal care in resource poor settings.

Findings from existing reviews of humanitarian logistics plans and supply chain management processes implemented in humanitarian response efforts, indicate that the amounts of resources gathered often depend on the pre-existing motivation of suppliers to donate, as well as on the familiarity and existing relationships with the donor community.⁴³ These research findings are further supported by the author's on-the-ground assessments of independent surgical team efforts in Haiti, which resulted in the

inability to utilize supplies that were brought by the surgeons or donated by the institutions they represented, as there were no facilities within which to operate, no electricity to power the devices and no access to equipment for sterilizing devices and surgical fields. This was a recurring event in the response to Haiti, as there was no coordinating intermediary entity to organize, inform and delegate surgical teams on the ground, and to also communicate changing supply needs and the infrastructural limitations specific to the delivery of orthopaedic care. An analogous finding was observed by the author in assessments of orthopaedic care delivery systems in district hospitals in Lusaka, Zambia. The results of inappropriate orthopaedic supplies in Zambia resulted in collections of unused C-arms, incomplete instrument and implant sets, which monopolized operating room space only to remain unused. Based on the case studies reviewed and the field assessments undertaken, which revealed the possible negative outcomes associated with uncoordinated efforts towards providing orthopaedic care in resource poor settings, an argument could be made for the need of an orthopaedic service and supply coordinating unit. In considering the requirements for meeting the resource coordination needs of an orthopaedic supply chain management system, a potential 'coordinating unit' would need to invest in cultivating relationships that will expand its network of corporate partners, and will bolster relationships that improve its capacity to coordinate. A potential partner in this network is the company Stryker, a manufacturer of orthopaedic equipment.

Stryker Trauma

An implant manufacturer that has made a commitment to develop a management process that allows for more effective deployment of its supplies during disaster response is

Stryker Trauma (Derek Grillo, Stryker Orthopaedics. January 2011). The participation by Stryker Trauma bears the potential of maximizing the alignment of core competencies and resources between a ‘coordinating unit’, the manufacturer, other donors and the potential satellite recipients. Given the challenges outlined above, a collaboration effort aimed at understanding the details of the corporation’s operations, practices, priorities and constraints has been undertaken. Through communications to date, it has been determined that for disaster management in particular, Stryker will benefit from a service in communicating information, and in coordinating resources and interdependent relationships between Stryker and recipient organizations. It will also help improve cooperation with other corporate donors to effectively coordinate several company-specific supply chains. The company’s interest in collaborating with a coordinating unit may encourage the participation of others and increases the opportunity for testing the proposal of a coordinating unit.

Discussion of the Applicability of a ‘coordinating unit’: Motivations and Challenges of Building Partnerships in Humanitarian Relief

The drive by corporations to contribute to humanitarian and relief efforts often stems from previous exposure or experience with the tremendous losses, business and otherwise, which are incurred when disaster strikes. However even beyond the business logic of working to alleviate economic losses that generally follow unpredictable disasters, the corporate sector is increasingly under pressure to exhibit corporate social responsibility, from several groups including employees, consumers and investors. Reports indicate that corporations with internally driven corporate social responsibility programs have displayed improved employee recruitment, retention and satisfaction.⁴⁴

The case could be made that if corporate involvement were to increase, it would be most effective if carried out in collaboration with existing country specific organizations that are equipped with local expertise, knowledge of existing infrastructure, legitimacy and trust of the community as well as informal leadership and regional familiarity. These are all essential elements in the assessment and planning of response efforts. From the perspective of the NGOs, it is certainly the case that the increasing scale of unpredictable disasters has rendered their ability to meet on the ground needs and demands extremely difficult if not impossible. In particular, the limiting stream and time-structured provision of their funding requires NGOs to continually use their resources to support daily needs. Thus their ability to invest in developing critical infrastructure, management, information and logistics systems is extremely compromised. An additional constraint rests in the limited supply and high turnover of staff, which NGOs often struggle with. This constraint makes the creation of additional expertise, the transfer of training and knowledge in the organization difficult to justify and maintain, and often unfeasible to financially support.

The challenge of equipping NGOs with the capacity to develop their logistical support systems and to take on the task of coordinating relief efforts on the ground, will require national scale efforts that have historically been slow to form and that are logistically and financially impractical to overcome in the near term. Information and supply management systems will require long-term investments, restructured funding mechanisms and sustainable sources of national funding. They will also require significant recruitment, training and retention of personnel, and the existence of an in-country infrastructure that will provide the large-scale coordination necessary to deliver

effective relief in disaster settings. The immensely demanding nature of this task and the long timeline necessary to potentially implement it, highlight the need to develop alternative options for strengthening current medical relief efforts in disaster settings. The particular case of orthopaedic surgical care delivery poses even greater challenges, as it is not a supply base that falls under the umbrella of any large relief organization. This renders the accurate assessment of needs, rapid collection, appropriate distribution and coordination among the facilities particularly challenging.

The investment in strategic partnerships that maximize the complementary contributions of local organizations and orthopaedic supply corporations, through a facilitator with full knowledge of the strengths, weaknesses and cultures of both entities will allow for greater coordination of efforts among organizations and corporations. It will also allow for greater accuracy in providing supplies that directly meet the demand.

Public-Private Humanitarian and Business Partnerships

Through efforts to understand the needs for collaboration with Stryker Trauma, several significant issues surfaced. The first is with regards to the preliminary position that corporate executives wish to identify, that is the level of company participation they wish to commit to within a corporate-NGO partnership. For some, participation will only consist of donations and contributions of cash and resources. For others it will consist of system level efforts to improve the process of delivering aid through an integrative partnership, which maximizes the basic competencies of both organizations.⁴⁵ This more involved partnership requires a greater level of sustained commitment to the provision of resources and a mutual dedication to the maintenance of the partnership, however having an expert facilitator to broker the partnership decreases the coordination demands placed

on both parties. The carefully planned coordination provided by a facilitator such as a ‘coordinating unit’, will also maximize the impact of supplies donated by corporations. It will allow supplies to be accurately and rapidly distributed and better accounted for, and will result in improved outcomes to be demonstrated to stakeholders—a task that is becoming more important to fulfill. Furthermore, the option of having an intermediary facilitator between receiving organizations and donor corporations presents an opportunity for companies to pool their efforts under the umbrella of one single organization. This would allow for improved coordination of efforts, a reduction of duplication, and an enhanced efficiency of the donation process to produce a greater impact for the recipients of donation efforts, whether during disaster response or otherwise.

Implementing Concept of a ‘Coordinating Unit’ in Disaster Relief

During large-scale disaster relief efforts, and particularly in the immediate response phase, humanitarian supply chains emerge as an expansive list of public and private organizations that are providing aid to affected individuals. The surge of aid in this phase is often received in the absence of the logistics systems necessary to increase the speed of delivery, the accuracy of supplies requested and deployed and the sharing of information between organizations to improve the efficiency of operations.⁴⁶

Information during disasters is constantly changing and often incomplete, resulting in gaps of knowledge that render the analysis of needs and of operational capacities difficult if not impossible to obtain.

A ‘coordinating unit’ can enter this chain of events to help organizations and corporations identify what they need to know, and to assist in facilitating the communication of

information between them. As a neutral third party NGO, the ‘coordinating unit’ will bring together multiple companies that are each partnered with both separate and overlapping organizations. This will effectively lead to a multiplied impact of donations and resources, and a heightened effect of many best company practices that can improve disaster response capacity. One example of this integrated system of an alliance of organizations managed by a single entity is found in the Partnership for Quality Medical Donations (PQMD). As previously mentioned, PQMD was founded to develop and propagate improved standards for the delivery of medical products to the underserved, including disaster stricken victims.⁴⁷

PQMD works as a liaison for the multitude of actors involved in disaster relief. In doing so it promotes reliable donation procedures by both donor firms and recipient organizations. It also promotes sound donation practices, supports and encourages best practices, and insures that appropriate medical products are delivered to provide disaster relief and to build basic healthcare infrastructure. The value that PQMD brings lies not only in its facilitation of making available corporate donated medical supplies from its partners, but also rests in its continued impact on the building of trust and understanding between the partner corporations and agencies. This trust helps to bring forward the opportunities for maximizing the assets and expertise of both.

PQMD also has an emergency response bracket led by industry and NGO leaders, which is activated to assemble during the relief response phase of a disaster. It functions to mediate communication and collaboration between the two sectors in order to best evaluate and respond to on-the-ground needs. The ‘coordinating unit’ will effectively provide a service parallel to PQMD’s disaster relief branch, which will uniquely focus on

bridging efforts between the “many” nonprofit agencies and “many” orthopaedic supply companies to provide relief through improved supply chain management.

Comparative Advantage of Enlisting a ‘Coordinating Unit’

With the recurrence of emergency supply chains and networks that are characterized as temporary, volatile, unpredictable and constantly evolving, the lessons learned from tragic instances such as Haiti will never amount to sustainable change.

Developing, supporting and investing in logistics information systems for humanitarian relief can help eliminate the health burdens and financial costs of inefficient relief efforts. The ability to assess, update and communicate real time needs will decrease duplicated efforts, inaccuracies and delays.

In an effort to support in country non-profit organizations towards more optimal and satisfactory handling of the logistics dependencies and failures that occur during disaster response, the ‘coordinating unit’ will serve as a neutral broker between humanitarian organizations and corporate partners. Based on the reviewed organizational models, the on-ground assessments, the corporation interest and the technical considerations discussed above, we can conclude that there is enough evidence to support the hypothesis that the creation of a ‘coordinating unit’ authorized to manage the process of orthopaedic donations and to coordinate all the stakeholders involved, will improve the delivery of musculoskeletal care in resource poor settings. We can conclude that a ‘coordinating unit’ may fill the present operational capacity chasm within the orthopaedic equipment supply chain. It will do so by providing the logistical management services necessary for delivering orthopedic supplies, and will base donation deliveries on recipients’ local capacity to provide orthopaedic care, their supply needs, the local healthcare

infrastructure, the providers' abilities to technically operate the supplies sent, or their access to acquire the necessary training. The 'coordinating unit' can also effectively contribute to the collaborative efforts that would maximize such partnerships, particularly for the provision of orthopaedic supplies, and can help build and sustain the much needed network of suppliers and recipient health organizations to provide optimal, timely, flexible and accurate delivery of care in disaster and non-disaster settings. Furthermore, through the creation of a 'coordinating unit', key organizations will be included in the supply chain of a "corporate partner, broker, and recipient" partnership that will afford them access to resources before disaster ever strikes.

Chapter 7: Second Hypothesis—*Implementation of a virtual and physical supply chain to improve the delivery of musculoskeletal care*

The second hypothesis claims that the implementation of a virtual and physical inventory and supply chain platform will improve the delivery of musculoskeletal care in low-income countries. This hypothesis proposes that there is a correlation between the optimization of existing orthopaedic supply delivery systems and the achievement of more adequate delivery of musculoskeletal care in resource poor settings. The questions posed to test this hypothesis seek to explore existing models of a dual virtual and physical inventory system, are intended to assess the feasibility of such a system in the management of orthopaedic supplies, and to predict the potential for such a system to improve the accountability and appropriateness of orthopaedic supplies provided in a design that improves the delivery of musculoskeletal care.

***How to Improve Donation Processes to the Benefit of Donors and Recipients:
Facilitation of a Virtual Inventory of Orthopaedic Supplies***

Research indicates that in contrast to the business sector, humanitarian agencies often do not rely on the tools of information technology to forecast demand or protect against shortages, as they often do not have sufficient control over the level of demand or the volume of supply. What humanitarian organizations generally do is share their local, national and international supply chain resources of donors and medical device suppliers, although with no single agency overseeing the process nor monitoring and evaluating the outcomes.⁴⁸ The absence of aggregate information collected on the operations of nonprofit humanitarian organizations both during disaster response and routine donor transactions—Information such as its supplier network, supplies and funds received, quantities delivered etc.—reduces the capacity for inventory optimization during times of increased need. Furthermore, this absence of information prevents the formation of collaborative networks of suppliers and recipients, as it provides no reliable source of information and no inventory data upon which to make donation and procurement decisions. Nonprofit organization leaders cited the lack of reliable information systems as well the lack of appropriate technology as reasons for the limited information capacity of many nonprofit organizations.⁴⁹ This certainly highlights that there is requisite for supporting the development and capacity of health nonprofit organization supply chains. An initial step, which would be well supported by an independent entity, would be to collect data on their operations, to record successes and failures, and to accordingly formulate strategies for improvement. This process can be facilitated by access to an interlinked virtual information platform that can be managed by a coordinating organization. However, while needed for strengthening the information gathering

capacities and the logistics capabilities of nonprofit organizations, supply chain management through a virtual interface alone is not necessarily sufficient to improve supply chain performance. The adoption of a culture of measuring inputs, outcomes, process and performance in the delivery of healthcare and surgical care in particular must be adopted by humanitarian organizations delivering this care, and will maximize the effectiveness of a virtual supply chain management system.

Virtual Inventory of Orthopaedic Supplies: Proof of Concept

Research on an organization with strong logistics expertise and a history of providing inter-agency services, the World Food Program, revealed that an effective logistics coordination platform should be made up of a virtual web, virtual participating corporations, a central unit and satellite offices.⁵⁰ This model could be adapted to form an orthopaedic virtual coordinating organization, which functions to recruit donors into a participatory pool on a virtual web platform, and also serves as the liaison to local humanitarian non-profit organizations on the ground (satellite sites). In the World Food Program model, the virtual web tool and central coordinating unit are set as permanent features of the platform, while the participating corporations and country-specific local pre-screened non-profit organizations generally evolve with each donation effort.

Organizational proof of the effectiveness of the virtual platform in disaster response is observed in the structure of the United Nations Joint Logistics Centre (UNJLC). The UNJLC is an interagency center that coordinates logistics for emergency response. It provides logistics support for operations planning, identifies bottlenecks that hamper relief efforts, and improves the function of individual organizations by communicating important logistics tools and coordinating activities of cooperating UN and non-UN

agencies.^{51 52}

Partnerships and Transitions to a Virtual Platform

To achieve effective collaboration between a coordinating unit, manufacturers, orthopaedic implant suppliers and recipients, towards designing a virtual management plan for the deployment of orthopaedic supplies, the appealing case for partnership must be made. In addition, a proposal for the transition from a physical network to a virtual platform for tracking supplies for donations in disaster and non-disaster settings must be outlined. A review of the literature reveals eight elements that are associated with effective transitions to virtual platforms. These elements include pre-qualification criteria, common goals, trust and culture, direction, supply chain design, marketing, finance and legal aspects, business process and information technology.⁵³ Sharing a common goal is often a pre-condition for engaging in a formidable partnership, and usually becomes the rate-limiting and determining step for building partnerships. Particularly in the case of corporate-nonprofit partnerships, the elements of trust and culture often substitute for the contracts and regulations that generally govern private institutions.⁵⁴ In addition, since virtual platforms have often been managed by voluntary collaboration decisions rather than by legally binding regulations, trust has been a critical factor for both the initiation and development of a virtual network of suppliers and recipients. It is an ingredient that has created greater incentives for cooperation, and has encouraged the sharing of information necessary for dealing with uncertain situations.⁵⁵ Trust in a proposed partnership between donors, recipients and a coordinating unit, essentially entails a description of proposed goals, anticipated risks, costs and benefits of the partnership. Among the many advantages of information technology systems are the

decreased transactions costs that result from coordination efforts to minimize duplication. Also expected are the dynamic capabilities of the platform to meet changing demands, to create learning opportunities, and streamline logistical structures, in which the adoption of information technology platforms would be instrumental and necessary.

The establishment and use of a “virtual warehouse” software program, could provide a basic foundation for documenting donations operations, and manage the interactions between donors and recipients. By requiring reports on the use of supplies, it could provide organizations with a framework that can be used for training workers to diligently perform assessments and to maintain inventories.⁵⁶

Value of Pre-Positioned and Warehoused Emergency Orthopaedic Supply Packs

The distinct element of orthopaedic supply donations is the need for the expertise of orthopaedic surgeons who can assess injuries, diagnose and delineate the surgical procedures indicated and the supplies needed. Thus while it is paramount for NGOs to develop and strengthen their logistics systems to be utilized during disaster response, there is also great value in pre-positioning basic orthopaedic emergency supplies, particularly orthopaedic supplies that can be immediately deployed for use. Based on a recent history of natural disasters with a disproportionate percentage of orthopaedic injuries, a retrospective study of case logs could be conducted where data exists, in order to build a summary of the types of injuries suffered and the procedures necessary to surgically treat them. An assessment of the 2005 Kashmir earthquake from an orthopaedic trauma lens revealed the following most common injuries: Femoral Fractures, Tibial fractures, Unstable pelvic ring fractures, and compound fractures of the humerus, as well as closed soft tissue injuries.⁵⁷ All cases recorded in this study were

initially managed with external fixation, while unstable metaphyseal and intra-articular fractures were treated with trans-articular fixation. The open soft tissue wounds were managed through debridement, lavage and drainage and left open under the assumption that the wound was still contaminated and could lead to a bacteremia and sepsis if closed with active infection. After stabilization with external fixators, most closed fractures (if diaphyseal) were managed by removal of the external fixator and placement of intramedullary nailing to ensure an aligned union.

A review of operative case logs collected at the four Haiti-based facilities of Partners in Health/Zanmi Lasante, revealed a total of 513 operations performed between January 12, 2010 and February 5, 2010.⁵⁸ Debridement and lavage accounted for the greatest percentage of procedures performed, adding up to 167 across all four sites. The next most common procedure was fixation of long bone fractures (external and/or internal), which constituted 18.5% of procedures performed (95 total). The choice of performing internal or external fixation varied across sites, and was generally based on the availability of equipment, as well as surgeon comfort level with the procedures performed in a compromised practice environment. For example 82.4% (14 of 17) of fixations performed at Hinche were internal, and 100% (13 of 13) of those performed in Petite-Rivière were external. At Cange, where the highest volume of procedures was performed, the distribution was more varied with 45.7% of fixation being internal (16/35). The amputation rate across all facilities was 9.7% (50/513). The remaining procedures included fasciotomies, reductions, laceration/repairs, split-thickness skin grafts (STSG), revisions of amputations, exploratory laparotomies, back immobilizations, unknown trauma and dressing changes.⁵⁹

While the aforementioned surveys do not provide a fully comprehensive profile of injuries and summary of procedures, they could be used to conjure up a list of the supplies needed to assemble an orthopaedic basic pack, which could be stored and immediately mobilized when necessary to treat injuries in the critical hours and days immediately following disaster. They could also be used to design basic packs that could be stored and used as needed in response to orthopaedic trauma injuries in resource poor settings. This list in its most basic form could include the following: an ortho-basic pan (including clamps, knife handles, elevators, retractors, mallets); plaster, gauze, ace bandages, k-wires, sterile saline irrigation, battery powered saws and drills, small fragment and large fragment plate and screw sets, external fixators and pins, smooth narrow nails that can be placed unreamed without fluoroscopy, as well as intramedullary rods.⁶⁰

While insufficient as a single and uncoupled response, the prepositioning of supplies will bridge surgical relief efforts between the time disaster strikes, and the time that the virtual network of suppliers and recipient organizations becomes activated to donate and distribute resources. However it is also the case that the pre-positioning of supplies could be costly, and that obtaining access to these stored supplies could be inhibited by unanticipated external events, or unexpected damage onsite. This does not refute the importance of securing pre-positioned supplies, but points to the need to identify and stockpile inventory at more than one warehouse facility, and in locations within close proximity to disaster prone regions.⁶¹ It then will also rely on the virtual platform to meet the on-going changes in supply demands, as it would be improbable for pre-positioned supplies to meet the entire volume of emergency supplies needed (Christopher Born MD,

Personal Communication, 2 March 2010). Thus part of what remains to be determined, is a method for forecasting the composition and volume of supplies to be stored as well as the number and locations of warehouses to be established, within the limits of financial restrictions. A guiding model for determining the details of such a model is the AmeriCares model of disaster preparedness and response. AmeriCares is a nonprofit humanitarian aid organization, which supports both stable humanitarian assistance programs and immediate disaster response emergencies. Its model for obtaining relief supplies entails a year-round receipt of medical supply donations from pharmaceutical and medical device corporations, and the storage of these donations in three warehouses based in the U.S., Europe and India, where they can be immediately mobilized as necessary. Upon the strike of disaster the organization deploys a team of relief experts to work with partners on the ground to assess needs and itemize the list of requests. This list is then used to search the warehouse inventory, with all available items immediately shipped and those not available being placed on an “additional supplies” list. The continuously updated additional list would then be communicated to partners and donors who have the capacity to fill the supply gap, with a request for their contributions. This model could be adapted and amended to support the provision of orthopaedic supplies. Then through a dual plan of pre-positioned supplies and virtual replenishment network, surgeons will be expected only to travel to the disaster site, with the supplies present to meet them at the facility. In this process the facility (i.e. Hospital or Clinic) would be held accountable for ordering, receiving and recording their receipt of supplies to be used for managing future transactions both during disaster and non-disaster scenarios.

Challenges with Implementing a Dual System of Virtual Inventory and Pre-Positioned Physical Inventory

A principle challenge that underlies the development of a dual system of a virtual supply chain and pre-positioned stock of orthopaedic equipment, is that its success and sustainability largely hinges on the involvement of manufacturers and corporate partners. The limited commitment by corporations and non-profit humanitarian agencies to invest in partnerships can be attributed to several causes. In general, the incongruities in the working cultures of business and non-profit entities (particularly at the outset) may be contributory to the difficulties of initiating a partnership.⁶² To minimize the impact of the differences, efforts must be made to provide clear and frequent communication, specific and focused goal alignment and meticulous management of expectations in the partnership. However several challenges are more specific to the creation of a ‘coordinating unit’ that will link donors and recipients. These include the relative lack of control that corporations perceive they have over the outcomes of their donation efforts, since the allocation decisions, implementation efforts and evaluation measures will be undertaken by a separate entity. This disconnect also leads to further diffusing the obligation that manufacturers and corporations have towards building or maintaining a commitment to their recipients, as they may perceive minimal influence, limited involvement and thus a lower stake in the partnership. An additional challenge is associated with the relative scale and size of an intermediary central unit. Even in meeting corporate social responsibility objectives, the corporate partner must have a valid business case that provides legitimacy to their stakeholders who may question the choice to engage in the partnership. This pressure to deliver and the drive to reduce the risk of such partnerships can often influence corporate leaders to partner with large widely

known organizations. Especially organizations bearing a history of exceptional performance and reliable results, which would provide great visibility, positive branding and large networks for corporations to access while meeting their corporate social responsibility commitments.⁶³

However beyond the differences, businesses are motivated towards partnering by factors such as increased access to learning logistics and supply chain management, in unpredictable and unstable environments where partners will reside. Other drivers include an expanded network, an opportunity to provide a public good while highlighting the philanthropic branch of the company, and finally an increased level of staff motivation that will likely ensue secondary to philanthropic action by the corporation.⁶⁴

A Proposed Model: An Orthopaedic Virtual and Traditional Supply Chain Management for Disaster Relief

As previously outlined, one branch of an orthopaedic-specific disaster response involves the creation of a virtual warehouse that is equipped to provide donations to prescreened sites around the world. Should disaster strike, this virtual warehouse will be used to supply the on-going needs of the disaster, as the philanthropic alliance members on the ground will be communicating their needs and capabilities in terms of injuries seen, infrastructure and human resources available. The organization managing the platform will be able to communicate these needs on an ongoing basis to the corporate alliance via a web-based software program. Essential to this course of action is the centralization of orthopedic donations. Donations will be matched to country-based NGOs and hospitals based on the needs communicated by providers on the ground. With needs and locations

expected to change, this process can assist in avoiding misappropriation that can come from transit and procurement delays.

With the potential applicability of this strategy, considering the interest communicated by Stryker in the wake of the events in Haiti, and the immense though fragmented private sector response that accompanied it, there exists an opportunity for piloting the proposed logistics platform for managing a humanitarian orthopaedic equipment supply chain.

Value Propositions to Donors and Recipients

The value proposition to Stryker Trauma as a corporate partner would include the following:

- Streamlining currently discordant donation processes to healthcare organizations
- Screening and mobilizing idle, surplus inventory to decrease warehousing and handling costs
- Certifying recipient sites to ensure donated equipment is provided to qualified surgeons and institutions
- Decreasing surplus inventory
- Tracking inventory donations and humanitarian impact
- The transparency of an online portal will allow for tracking donations that are either anticipated or in the pipeline of the supply chain. This will provide an outline of participating donors and provided donations, so as to avoid the inefficiencies of gaps and overlaps, while maximizing accuracy and coverage.
- Exposing surgeons in emerging markets to company products
- Enhancing public relations
- Fulfilling corporate social responsibility

On the receiving end of the donation process, the value proposition to participating members who are based or active in recipient countries includes the following:

- Networking and sharing of ideas between members of academia, NGOs, and advocacy organizations
- Linking with orthopaedic NGOs to identify recipient sites and surgeons
- Enhancing the efforts of current NGOs by providing a sustainable instrument and implant supply to sites at which they are already providing surgical training
- The transparency of an online portal will allow for tracking donations that are either anticipated or in the pipeline of the supply chain. This will provide an outline of participating donors and provided donations, so as to avoid the inefficiencies of gaps and overlaps, while maximizing accuracy and coverage.

Point-by-Point Description of Proposed Transaction Process

For both parties involved in a donor-recipient transaction, the process would be carried out as follows:

- Surplus inventory would be uploaded from corporate suppliers to the virtual supply chain platform managed by an organization that would function as the ‘coordinating unit’. The platform would be powered by Aid matrix (a humanitarian supply chain management) software program.⁶⁵
- The inventory would be made visible to partner hospitals and other organizations providing orthopaedic care in the developing world. Suppliers can indicate a preference for which regions their donations may be delivered to.
- Receiving hospitals and organizations would define and specify their donation needs, and make an inventory request through the Aid matrix online portal. With assistance from the ‘coordinating unit’, recipients can work towards prioritizing identified needs and providing general estimates of quantities required.
- The ‘coordinating unit’ will then facilitate the administrative procedures for receiving donations, in accordance with the WHO Guidelines for Health Care Equipment Donations.⁶⁶ Through its team of consulting orthopaedic surgeons, it will assess the requests placed, then prioritize and allocate the inventory appropriately based on guidelines, recipient needs and capacities, as well as supplier preferences and restrictions.

- The ‘coordinating unit’ would ensure that all supplies meet existing safety and performance specifications provided by the manufacturer. It would also ensure that donated equipment is fully operational, and that all essential accessories and supplies are available.
- The equipment would then be shipped directly from the corporate warehouse, with shipment tracking, receipt confirmation, and tax documentation provided by the ‘coordinating unit’. Once in-country, the processes of customs clearance, local transportation, unpacking, reception, storage and distribution can be executed by the ‘coordinating unit’, or a third party provider if recipients do not bear the capacity to carry out these functions.
- Once equipment is operational, an evaluation of the outcomes, effects and impact of donated supplies will be carried out by both donor and recipient, with assistance from the ‘coordinating unit’. This will foster communication and continued support, while identifying mistakes and learning opportunities for continued improvement of future donation efforts.
- In a disaster response setting, the ‘coordinating unit’ would supplement the responsibilities outlined above with the following:
 - The development of a general emergency orthopaedic supply list which may include an ortho-basic pan (including clamps, knife handles, elevators, retractors, mallets); battery powered saws and drills, small fragment and large fragment plate and screw sets, external fixators and pins, as well as intramedullary rods and SIGN nail sets when the expertise to use the sets is present.
 - This equipment would be stored at 2-3 warehouse sites which could be managed by non-profit third party warehouse providers.
 - Once disaster strikes, the ‘coordinating unit’ would deploy a team of relief experts to work with partners on the ground to assess needs and itemize requests.
 - The lists would be matched with warehouse inventory, with all available items immediately shipped and those not available being placed on the virtual online request portal. If the items are available on the online

inventory then the 'coordinating unit' will alert donors to mobilize these resources. If the supplies are not uploaded and thus unavailable online, then the 'coordinating unit' will communicate the need to donors and assist in mobilize the resources as efficiently and rapidly as possible. At this stage, both the pre-positioned supply chain and the virtual supply chain would be fully functioning.

- Recurrent costs for the 'coordinating unit' will be covered by a sliding scale annual fee provided by participating recipient organizations and contributing donors.

The strategy outlined above gathers from different elements outlined in the examples of virtual and physical pre-positioning of supplies that could be deployed in response to disaster, or for the sustainable provision of supplies. These included different concepts displayed in the example of the World Food Program, AmeriCares and in the model proposed by Orthopaedic Link. It is certainly the case that the decision to manage the system on a predominantly virtual interface is driven by the opportunity to provide a rapid, flexible and accurate response to unpredictable disaster, particularly in a setting of complex, fragile and unstable post-crisis environments. The virtual platform will facilitate interface between the key stakeholders of on the ground local organizations and corporate donors, and allow for subsequent coordination of inter-agency decisions and actions.

However, though there is reported success of the above-mentioned models, including availability of the validated instrument AIDmatrix for operationalizing a virtual platform, and there is evidence of the possibility to apply the basic elements of these models towards creating a step-by-step process for the provision of orthopaedic supplies, we cannot conclude that there is enough evidence to support the hypothesis that the

implementation of a virtual and physical inventory and supply chain platform will improve the delivery of musculoskeletal care in resource poor settings. Though the concept appears valid and implementable in theory, there are several hindrances that challenge the practical application of the model. Achieving stakeholder commitment towards donating supplies to a centralized virtual entity that would be controlled by an external unit is a primary challenge, which could be resolved by the recruitment of an organization that holds legitimacy in the field, but would take a substantial amount of time and validation to achieve. There are also obstacles in determining which recipients would be equipped to provide a “demand” list of supplies that would be delivered, or furthermore obstacles in equipping recipients with the capacity and expertise to determine and communicate these demands. This model also does not account for the implementation measures necessary for improving the delivery of musculoskeletal care, including the training needs, the infrastructural needs and the maintenance requirements. It is therefore the case that the establishment of a virtual and physical supply chain platform, while one element necessary for improving the provision of supplies necessary for the delivery of musculoskeletal care, is not sufficient for the sustained and safe delivery of such care.

Chapter Eight: Conclusions

It is the case that due to inadequate funding, hospitals in low-income countries lack the instrumentation necessary to surgically repair severely fractured bones, whether as a product of disaster or isolated local cases of musculoskeletal trauma. This research was aimed at determining a method to address only one essential element of providing adequate musculoskeletal care in low income countries, that of the growing need for

supply chain management and logistics to support the delivery of appropriate materials that are suited for local needs and capacities, so as to allow a benefit from the resources donated and to prevent complications and further injury (i.e. Injuries such as infections and non-unions, which could be caused by the improperly supported and implemented supplies).

In revisiting the question of how do donors, recipients and policymakers create a supply chain management system that most effectively equips surgeons in resource poor settings to deliver surgical care, several conclusions can be drawn. Both within everyday disaster and unique disaster contexts, prioritizing conduction of local needs assessments, providing opportunities for recipients to specify and communicate their needs, and confirming the presence of adequate local infrastructure and workforce capacity to receive and utilize donated equipment, are essential steps that should be executed prior to the deployment of donations. In addition, the presence of balanced communication between donor and recipient, with plans co-formulated by both parties, and the investment in monitoring the quality and integrity of complex implant sets, including the basic operational support systems, are elements necessary for maximizing the impact of donated supplies. Finally, and of great importance, the investment in logistical platforms and supply chains to manage donations is critical, and the coordination among multiple stakeholders by a central 'coordinating unit' that can assist in streamlining the process and creating a platform for symmetric information exchange is highly instrumental. This would allow recipient needs (i.e. demands) to be met by donor supply in a focused and targeted manner, and would begin to address the difficulty of choreographing the many efforts and significantly varied levels of expertise present in disaster relief efforts, as well

as asymmetric high and low-income country settings. While there are many challenges that can arise in working to foster necessary partnerships, and to incentivize accountability in donation efforts, they are often coupled with opportunities for working to improve outcomes. Opportunities can be found in the creation of systems that promote accountability through mediating communication, managing inventories, facilitating delivery and supporting evaluation.

In an effort to maximize utilization of corporate donations and the surgical capabilities of surgeons and healthcare workers on the ground, the creation of a ‘coordinating unit’ can provide a collaborative, analytic approach to assess need and inventory. The ‘coordinating unit’ would also function to warehouse, allocate and track orthopaedic implants and instruments through a virtual and physical inventory system, in a manner that enhances the provision of orthopaedic care.

However, while both donors and recipients will benefit from access to a combined inventory system, these services are not sufficient for improving the delivery of appropriate musculoskeletal care. To benefit from the proposed systems, organizations would need access to several elements that are not sufficiently accounted for in the proposed virtual platform model. For example, both the donor and recipient organizations would need to have access to relatively sophisticated technological platforms with the trained personnel to manage them, in order to participate in the system. Organizations would also need the critical clinical/orthopaedic expertise to assess and forecast demand, as well as to safely and sustainably utilize the donated supplies towards the delivery of appropriate care. In addition, recipients must have the infrastructure necessary to safely deliver care, including sterilization systems, functional

operating theatres, water, electricity and the personnel (surgeons and assistants) needed for providing care.

This research has displayed the multiple interdependent constraints associated with providing orthopaedic care in low-income and resource poor settings. These include limitations in human resources, care facilities, adequate devices and instrumentation, healthcare systems and logistics as well as finances and physical resources.

However despite these constraints, the study has also displayed that there are several instruments and innovative models that can be integrated to improve the achievement of appropriate and adequate musculoskeletal care in resource poor settings. This research specifically focused on one segment of the system for providing care, the process of supply donations, and aimed to identify strategies for rendering the process more accountable, coordinated and positively contributory towards improving the delivery of musculoskeletal care; such that when surgical treatment is indicated, the simplest, safest and most cost effective technique would be available for use. For orthopaedic trauma care, these basic techniques would include traction, intramedullary fixation with unreamed intramedullary rods, or external fixation. The models considered in this study ranged from the development of new hardware more appropriate for use in low income countries (I.e. without the reliance on fluoroscopy, and with the obligatory proof of training) as in the SIGN model, to those that proposed the development of a 'coordinating unit' that manages the collection and deployment of orthopaedic supplies in a demand driven accountable manner inclusive of local needs and local capacities, to assist both donors and recipients towards delivering appropriate and improved musculoskeletal care.

The study findings support the hypothesis that a 'coordinating unit' can provide a standard approach towards assessing need, capacity, and resource inventory, and can coordinate stakeholders in a manner that maximizes the use of individual and corporate donations, and supports the surgical capabilities of surgeons and healthcare workers delivering musculoskeletal care in low-income countries. However as was revealed in the consideration of a virtual inventory platform as a solution, the treatment of musculoskeletal injury in low-income and resource poor settings will require simultaneous improvement on several co-dependent requirements necessary for the successful delivery of care. These essentials include pre-hospital care and transportation, access to resuscitative care, the availability of healthcare providers and surgeons, access to radiographic imaging, the presence of anesthesia care (providers and supplies), availability of drugs and antibiotics, clean operating rooms with access to sterilization of instruments and space, adequate and complete fracture fixation implants and instruments, operating room staff, post-operative inpatient care and access to rehabilitation services necessary for recovery.⁶⁷

The questions posed in this research only begin to tackle the long list of inter-related needs, by focusing on the orthopaedic implant and instrumentation branch of the system of care. However it is certainly the case that improvements in this segment of the system of musculoskeletal care must be linked with investments in all the other essential elements, in order for the sustainable provision of musculoskeletal care in resource poor settings to be achieved.

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Appendix

Case example 1: United Nations Joint Logistics Centre (UNJLC)

Organizational proof of the effectiveness of the virtual platform in disaster response is observed in the structure of the United Nations Joint Logistics Centre (UNJLC). The UNJLC is an interagency center that coordinates logistics for emergency response. It provides logistics support for operations planning, identifies bottlenecks that hamper relief efforts, and improves the function of individual organizations by communicating important logistics tools and coordinating activities of cooperating UN and non-UN agencies.⁶⁷ While the UNJLC performs many large and small scale functions, the element relevant to this brief is its role as an information platform that supports the logistics operations of relief organizations (medical and non-medical) on the ground. During its operations in response to the Mozambique floods in 2000, the virtually organized logistics structure of UNJLC displayed the value of having a central unit that operationalizes a web platform, carries out assessments, provides forecasts of needed goods, works to collect donations and in carrying out these actions provides continuity.⁶⁷ It was able to quickly and cost-effectively pull resources made available through its network, and was able to accurately and rapidly serve the function of information brokerage in a rapidly changing environment through the contributions of participating agencies. The use of the virtual platform in this case allowed for the real time flow of information that contributed to coordination and decision-making. This system effectively equipped small NGOs with access to resources previously only available to large multilateral organizations.

A 'coordinating unit' could effectively be positioned to provide a similar structure for the specific deployment of orthopedic supplies needed during unpredictable natural disasters, which create a large burden of orthopedic injuries. It will be equipped to quickly activate and amass supplies from a chain of orthopedic supply warehouses from many corporate partners, allowing for a quick adaptation of donations to meet rapidly changing needs in an unpredictable disaster environment. It will also enable coordination and linkage between corporations and recipients, as well as coordination and collaboration among participating corporations.