Orthopaedic Knowledge Update®

OKU® 6

Trauma

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Trauma

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Preface

Orthopaedic Knowledge Update®: Trauma 6 is the latest edition of the *Orthopaedic Knowledge Update®* series, and this text builds on the previous editions. *OKU® Trauma 6* is comprehensive and current in its content and includes new chapters on biomechanics, osteoporosis and pathologic bone, deep vein thrombosis (DVT) prophylaxis in patients with fracture, acute compartment syndrome, and biologic adjuvants for fracture healing. This publication is detailed in the latest evidence regarding diagnosis, treatment options, surgical techniques, and outcomes for the treatment of patients with orthopaedic trauma and fracture. It is the hope of all who were involved in this endeavor that surgeons can use this book as a reference for maintaining and updating clinical competence and improving patient care. The editors would like to express their gratitude to all of the chapter authors who spent many hours reading the current literature and writing and revising their manuscripts to produce these excellent chapters. The section editors (Daniel Dziadosz, Alex Jahangir, Mitchell Bernstein, Stuart Gold, Anna Miller, Philip Wolinsky, Andrew Choo, Milan Sen, Jonathan Eastman, H. Claude Sagi, Reza Firoozabadi, Hassan R. Mir, Derek Donegan, and Julie Switzer) were very conscientious and worked tirelessly while reading and editing these chapters and were persistent in making sure that the final product was outstanding.

The General Topics section includes chapters dedicated to new technologies in orthopaedic trauma, minimally invasive fracture management, outcomes of musculoskeletal trauma, osteoporotic fractures, and DVT prophylaxis for patients with fractures. The Nonunions, Malunions, and Infections section deals with surgical options, adjuvants for fracture healing, and new innovations in the management of these difficult cases. The Soft-Tissue Injury and the Patient With Polytrauma section consists of chapters discussing the evaluation and management of the mangled extremity, traumatic amputations, disaster and mass casualty preparedness, and the critical issue of damage control orthopaedics in the patient with polytrauma. Chapters in the Upper Extremity section are inclusive from the clavicle to the hand for fracture management and the assessment and management of traumatic nerve injuries. The acute evaluation of pelvis and acetabulum fractures as well as imaging, initial and definitive treatment, and functional outcomes are discussed in the Axial Skeleton: Pelvis and Acetabulum section. The content in the Lower Extremity section is all inclusive, from femoral head fractures to foot fractures and dislocations. The Geriatrics section includes chapters on not only hip fractures but also osteoporosis, pathologic fractures, and periprosthetic fractures.

The treatment of patients with fractures and trauma is an always-evolving field with innovations, tricks, and techniques improving constantly. The surgeon must stay current with the latest management options to understand the risks and benefits associated with these procedures. Some of these advancements need to be looked at with a critical eye and newer may not always be better. The contributors to this book face this dilemma daily and understand the significance of their role in distilling these newer technologies to those that actually are improvements in patient care.

This publication would have not been possible without the capable stewardship of members of the AAOS staff, including Hans Koelsch and Lisa Claxton Moore, and the Wolters Kluwer staff, including Brian Brown, Stacey Sebring, and Sean Hanrahan, who through numerous conference calls and poking and prodding kept this publication on track.

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CHAPTER 1

Outcomes of Musculoskeletal Trauma

DAVID SHEARER, MD, MPH • SAAM MORSHED, MD, PhD, MPH

ABSTRACT

There is ever-increasing demand for high-quality clinical outcome research to guide decision making. A framework for specifying a study's patient population, interventions, comparisons, and outcomes of interest (the PICO framework) has become vital to understanding the design and interpretation of clinical studies. The target population to which inferences can be applied often is defined by patient or injury characteristics as well as the treatment of interest. The risk of bias in a study is determined by the manner in which patients are selected for a study, whether treatment is allocated in a random or nonrandom manner, and how predictors and outcomes are measured. The spectrum of outcome measures ranges from surgeon-reported outcomes such as radiographic healing and revision surgery to patient-reported outcomes. Several instruments to measure generic and disease-specific patient-reported outcomes may be suitable for orthopaedic trauma research, depending on the application. Dynamic instruments developed during the past decade may offer improved test precision and ease of administration.

Keywords: clinical outcomes; fracture healing research; research methods

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INTRODUCTION

Demand continues to increase for sound research rather than expert opinion to form the basis of clinical decision making in the field of orthopaedic traumatology. During the past decade, there has been an unprecedented investment in high-quality multicenter clinical studies. At the same time, academic pressure to publish research in the ever-increasing number of journals has led to a similar or greater increase in the volume of low-quality studies.[1,2] Regardless of whether an orthopaedic traumatologist's desire is to become actively involved in clinical investigation or simply to interpret the growing body of medical literature, it is important to have a basic understanding of research methodology and the common instruments used to report outcomes. The use of clinical outcome instruments as a quality metric appears to be increasing and in the future may be linked to physician reimbursement.[3,4]

The population-intervention-comparison-outcome (PICO) framework is used to highlight fundamental principles of clinical outcome research. Several outcome instruments are commonly used in orthopaedic trauma, and the use of new instruments is likely to increase in the future. The publication of major clinical trials in orthopaedic trauma and their most important findings have had an effect on the field in recent years.[5-10]

THE PICO FRAMEWORK

Population

The first step in developing a research question is to define the patient population under study. The eligibility criteria, as described in a published research article's methods section, typically include age range, injury characteristics, time period, location, and other key characteristics. As criteria specificity increases, the study population becomes more homogeneous, and the resulting outcomes may have decreased variability. However, the downside of stringent eligibility criteria is that recruiting adequate sample size

may be more difficult. In addition, study results may become difficult to generalize to a broader population. More pragmatic clinical trial designs with inclusive eligibility criteria are becoming more common and may have more generalizable conclusions.[11,12]

The AO/Orthopaedic Trauma Association (AO/OTA) fracture classification provides well-defined, specific definitions for studies involving patients with a fracture.[13] The AO/OTA classification uses an alphanumeric code to identify each fracture pattern. Although the subdivisions of the AO/OTA classification are not always useful in a clinical context, the specificity of the AO/OTA subdivisions is useful in describing a patient population for research purposes.

Intervention and Comparison

Hypothesis-driven research often compares two or more interventions or treatment strategies. A surgical treatment may be compared with nonsurgical treatment, or different surgical techniques may be compared. The comparison may not be directly related to the surgery, as in a comparison of rehabilitation protocols or postoperative pain management strategies. Within the PICO framework, the new treatment typically is considered the intervention, and the standard of treatment is considered the baseline (also called the comparator).

The method of assigning patients to a treatment is a key component of the study design. In an ideal experimental model, every participant would receive both the intervention and the comparison treatment and thereby would serve as a perfect internal control. Because this ideal usually is not possible, studies are designed to create patient groups that are as similar to each other as possible. The benchmark method is random assignment to treatment, typically by using sealed envelopes or a computer program. Some methods, such as assigning treatment using a medical record number, allow assignments to be predicted and can introduce a patient selection bias; the use of such a method is called pseudo-randomization. Randomization can occur at an individual or group level. Randomization of groups, or cluster randomization, is a common feature of pragmatic clinical trials and may be appropriate for interventions that can be administered at a community or hospital level. These trials can achieve larger sample sizes and are more generalizable than results from more explanatory, individually randomized clinical trial.[11,12]

Study designs that do not assign treatment according to an experimental protocol but rather by provider preference or an existing clinical protocol are considered to be observational. Treatment groups in an observational study may have important differences that are associated with the outcome, which can lead to confounding bias. In fracture studies, injury severity is a common source of this type of bias. The chosen treatment often differs based on injury severity, and severe injuries by their nature have a worse outcome. A key characteristic of a confounder is that it is associated with both the exposure (intervention) and the outcome.

In addition to randomization, study design features that can be used to prevent confounding include matching and restriction. In matching, patients in the intervention and comparison groups are selected based on shared characteristics that can lead to confounding, such as age or injury severity. For example, each patient with diabetes who is assigned to the intervention is matched with a patient with diabetes who is assigned to the comparison treatment. The restriction strategy is similar to matching except that patients are simply excluded from the study if they do not fall within the specified range of potentially confounding variables. In the example, restriction would be achieved by excluding all patients with diabetes. The disadvantages of the matching and restriction strategies are that sample size is limited, the between-group effect of the confounding variables cannot be compared, and unknown or unmeasured confounders cannot be accounted for.

Statistical methods can also be used to control for confounding after the study is completed. Stratification divides the study subjects into subgroups defined by potential confounding variables. The effect of the intervention is assessed within each homogeneous subgroup, and the effects are pooled using a statistical weighting method such as the Mantel-Haenszel test.[14] Alternatively, confounding can be accounted for by conducting a multivariate logistic regression analysis that computes a unique odds ratio for each variable included in the model. Both of these methods can control only for measured confounders. This limitation affects all methods to reduce confounding, with the exception of randomization. Randomization creates equivalent groups even with respect to confounders that cannot be predicted or measured in advance.

The timing of data collection with respect to the intervention and outcome is another important distinction in categorizing research studies. Studies that begin collecting data before the outcome has occurred are considered prospective. Researchers first enroll patients in the study and then wait for the outcome to occur. In contrast, retrospective studies are initiated after the outcome has occurred. Data often are obtained from the medical record, and the quality of the data can be limited because many variables are not recorded or are inaccurately recorded. By definition, a retrospective study always is observational because patients were assigned to the treatment group before the study was initiated.

Outcomes

The variety of potential outcomes that can be selected for a clinical research study can make it difficult to choose the best instrument and understand its interpretation. The Wilson-Cleary conceptual framework for evaluating

outcome measurements considers the pathway from the patients' underlying altered physiology to mental and physical symptoms to overall health-related quality of life (HR-QOL)[15] (**Figure 1**). Opportunities for measurement exist at each step along the pathway. For example, at one end of the spectrum is plain radiography, which commonly is used in trauma studies to assess bony healing and alignment even though radiographic measures of alignment may not be correlated with the patient's subjective experience of pain or functional ability. Moving toward the other end of the spectrum, outcome measures such as a pain scale, strength, or range of motion testing may not be correlated with the patient's overall HR-QOL. Clinician-centered or surgeon-centered outcomes tend to differ from patient-reported outcomes (PROs), and there is an increasing emphasis on the use of PROs in clinical research. It is important to note that instruments that measure HR-QOL can be affected by an unrelated medical or nonmedical factor (such as comorbidities or psychosocial support, respectively). In addition, these instruments often do not explain identified differences in HR-QOL. For example, an intervention for a fracture may demonstrate an improvement in HR-QOL, but the question remains regarding whether the improvement is attributable to the patient's healing rate, limb alignment, or self-efficacy. Only by measuring outcomes across the spectrum can this question be answered. For that reason, investigators should consider administering PROs that measure HR-QOL in conjunction with other secondary outcome measures across the outcome spectrum.

ORTHOPAEDIC TRAUMA OUTCOMES

Clinical End Points

Bony union is one of the primary goals of fracture management. Because fracture union is a process that occurs across a continuum rather than as a discrete event, it can be as problematic as the primary end point of a research study.[16,17] Union has been defined as an event ranging from painless weight bearing to bridging of three of four cortices on orthogonal plain radiographs, but the reliability of these assessments is poor.[17] The Radiographic Union Score for Tibial Fractures (RUST) is a relatively new measurement based on assessment of cortical bridging.[18,19] Each cortex (medial, lateral, anterior, and posterior) is assessed and assigned a point value (1 = fracture line,

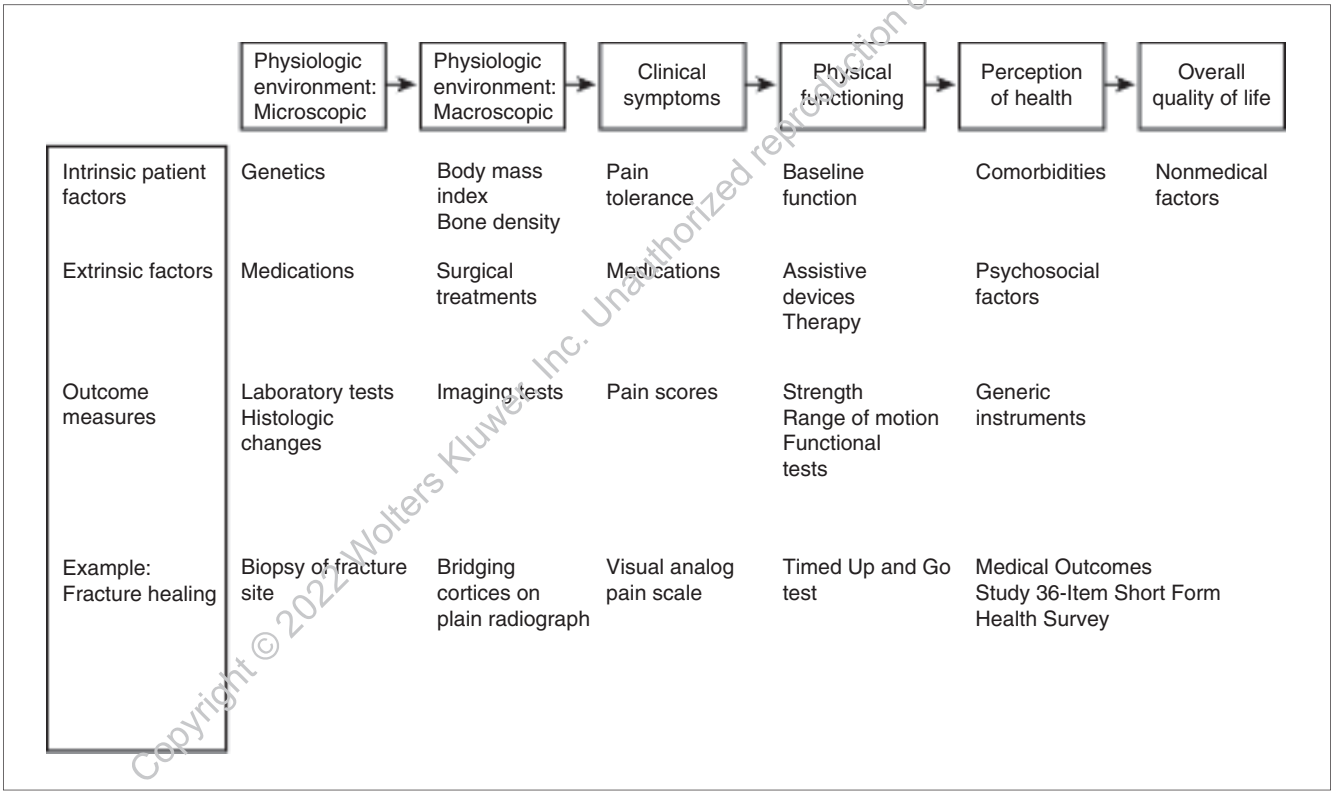

FIGURE 1 Schematic diagram showing a conceptual pathway for relationships among the components of HR-QOL, from the underlying causes of disease to clinical symptoms to overall quality of life. At each step on the pathway, intrinsic and extrinsic factors can influence the subsequent step, and opportunities exist for outcome measurement. Outcomes toward the left that measure the root cause of clinical symptoms, such as plain radiographs, may be highly sensitive to intervention, but not necessarily have a measurable effect on patient quality of life. Quality-of-life instruments, in contrast, may be less sensitive to change due to influence from external factors, but they measure an outcome that is unequivocally important to patients: improvement in quality-of-life.

no callus; 2 = fracture line, visible callus; 3 = no fracture line, bridging callus). The total score of the four cortices, ranging from 4 to 12, may represent the continuous nature of fracture healing, and the reliability of the RUST score was found to be higher than bridging of three of four cortices or orthopaedic surgeons' subjective impression of union.[20] The RUST score has now been modified to a four-level assessment of each cortex and validated for use in both the tibia and femur.[21] In addition, the Radiographic Union Scale for the Hip is now validated as a method for assessing healing of both femoral neck and intertrochanteric hip fractures.[22,23]

Revision surgery is another clinical end point that is relevant to patients.[24] Mortality may not be significantly affected by orthopaedic treatment, and revision surgery offers an alternative objective end point that is more likely to differentiate between fracture interventions. The common criticism of revision surgery as an outcome is that it relies on the subjective assessment of the treating surgeon. This objection can be overcome by strictly defining the criteria for revision surgery. Large studies often use an independent adjudication committee to assess whether the criteria for revision surgery have been met for each affected patient.[25]

Functional Outcomes

Most orthopaedic interventions are intended to improve function. A variety of outcome instruments directly measure physical functioning and performance. Among the most well-known of these is the Timed Up and Go test, which measures number of seconds required for a subject to stand from sitting, walk 10 feet, and return to a seated position.[26] This test is particularly useful for assessing the functional capacity of older adults, and the results of the test as administered soon after hemiarthroplasty for femoral neck fracture were found to be correlated with the long-term outcome.[27]

Wearable devices that record physical activity provide a means of measuring function that is increasingly available because of technologic improvements. Pedometers, which record each step, have been in existence for centuries, but recently more advanced devices (such as the Fitbit) have gained popularity with consumers and researchers alike.[28] Accelerometers are similar in principle but have the ability to differentiate low-intensity and high-intensity activities. Modern accelerometers can detect movements in three-dimensional space. The use of these devices in fracture studies has been limited, but as the technology is incorporated into smartphones and other wearable devices, a plethora of data increasingly can be harnessed to measure outcomes.

Questionnaires

Outcome questionnaires can be broadly categorized as generic or disease specific.[24] Generic instruments attempt to capture the overall quality of life in a metric that is comparable across a variety of different diseases. Because these instruments must capture many different aspects of HR-QOL, they may lack the granularity and responsiveness desired by researchers studying a specific condition. For that reason, a large number of disease-specific and body region–specific instruments have been developed and validated (**Table 1**).

The process of selecting the appropriate instrument for a study is driven by factors including validity, reliability, and practicality of administration. Validity is related to the content of the questionnaire and the ability of the survey to appropriately reflect changes in the study participants. Studies ideally use instruments previously found to be valid in the study population. Reliability refers to the precision and reproducibility of an instrument. Practicality includes factors such as length of time required to complete the questionnaire. The properties of several of generic instruments are outlined in **Table 2**.

Medical Outcomes Study 36-Item Short Form Health Survey

The 36-Item Short Form (SF-36) Health Survey was developed for the Medical Outcomes Study, a cohort study that in the 1980s compared clinical outcomes in different healthcare delivery systems.[29] The SF-36 subsequently became the most widely used generic survey in medicine.[30] The 36 questions in eight domains yield a physical component score and a mental component score. The SF-36 uses a proprietary system in which scores range from 0 to 100 with a mean of 50 and an SD of 10; a higher score reflects better health. To reduce the burden on study subjects and improve the ease of administration, the SF-12 was developed using a 12-item subset of the SF-36. The SF-6D, another subset of the SF-36, uses 11 items from six domains of the full questionnaire. Unlike the SF-36 and SF-12, scores on the SF-6D have been correlated with utility, a concept from economic theory that attempts to quantify an individual's preference for a given health state from 0 to 1 (1 is perfect health, and 0 is equivalent to death). These results are useful for direct input in economic analysis.

EQ-5D

The multinational EuroQol Group developed the EQ-5D instrument in the 1980s as a short, practical questionnaire that can accurately estimate an individual's quality of life.[31] The EQ-5D is significantly shorter than many other generic surveys; it has only five questions on mobility, self-care, usual activities, pain or discomfort, and anxiety or depression. Unlike the output of the SF-36 but similar to the SF-6D, the output of the EQ-5D has been correlated with utility preference weights. The EQ-5D is therefore a useful instrument to consider if economic analysis is

Table 1

Injury-Specific Outcome Instruments Commonly Used in Orthopaedic Trauma Studies

Injury	Instrument or Instruments
Upper extremity	Disabilities of the Arm, Shoulder and Hand
Shoulder	American Shoulder and Elbow Society Shoulder Scale
	Constant-Murley Shoulder Score
Elbow	Mayo Elbow Score
	American Shoulder and Elbow Society Elbow Scale
Wrist and hand	Patient-Rated Wrist Evaluation
	Michigan Hand Questionnaire
Pelvis	Merle d'Aubigné Score (Acetabulum)
	Majeed Score (Pelvic ring)
Hip	Western Ontario and McMaster Universities Osteoarthritis Index
	Harris Hip Score
	Oxford Hip Score
Knee	Knee Injury and Osteoarthritis Outcome Score
	Lysholm Knee Scale
Foot and ankle	American Orthopaedic Foot and Ankle Society Score

planned or a shorter survey is preferred. However, ceiling effects are common, which can make it difficult to identify differences in high-functioning populations. In particular, the EQ-5D has been problematic in differentiating outcomes from musculoskeletal problems involving the upper extremity.[32]

Musculoskeletal Function Assessment

The Musculoskeletal Function Assessment (MFA) questionnaire commonly is used in orthopaedic studies as a generic instrument for evaluating musculoskeletal conditions. The full MFA has 110 items, and the Short Musculoskeletal Function Assessment (SMFA) questionnaire has 46 items.[33] The ease of administering the SMFA compared with the MFA has led to its becoming the more commonly selected measure in fracture studies.[34] However, in the Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures evaluation of reamed and unreamed nails for tibial shaft fractures, the SMFA was not believed to add any information beyond that provided by the SF-36 instrument, and the researchers concluded that using the generic instrument was preferred to allow broad comparisons across disease states, at least in patients with a tibial shaft fracture.[35]

Sickness Impact Profile

The Sickness Impact Profile (SIP) is a generic instrument developed in the 1970s to quantify an individual's quality of life by assessing the ability to perform daily activities.[36] The survey consists of 136 questions in a yes-or-no format; the final score is derived from the percentage of affirmative answers. The 12 domains of the SIP are ambulation, mobility, body care and movement, social interaction, alertness behavior, emotional behavior, communication, sleep and rest, eating, work, home management, and recreation and pastimes. The Lower Extremity Assessment Project used the SIP as the primary outcome measure and found no significant between-group differences in the scores of patients with severe lower extremity injury who were treated with amputation or limb salvage[5] (**Table 3**). However, analysis of the subset of patients with foot and ankle trauma revealed that those who required a free tissue transfer or ankle fusion had worse SIP scores than those with below-knee amputation.[39]

Patient-Reported Outcomes Measurement Information System

In response to the growing demand for PROs, the US National Institutes of Health funded the Patient-Reported Outcomes Measurement Information System (PROMIS), a multicenter cooperative that developed an improved outcome instrument using technology and psychometric theory.[40,41] PROMIS is unique in that it allows items to be selected from several different item banks, each developed to measure specific domains such as extremity function or pain. Domains can be further profiled into physical, mental, and social health. PROMIS measures can be administered in three different ways: (1) short form assessments using a static subset of a domain's item bank;

Table 2

Characteristics of Several Generic Outcome Instruments

	Medical Outcomes Study 36-Item Short-Form[a]	Sickness Impact Profile[b]	EQ-5D[c]	Short Musculoskeletal Function Assessment[d]	Patient-Reported Outcomes Measurement Information System[e]
Scoring					
Lowest score	0	0	−0.59	100	10
Highest score	100	100	1.0	0.0	60
Total range	100	100	1.59	100	50
Mean score	50	—	—	12.7	50
Minimal clinically important difference	Overall Score: 3 to 5 Physical Component Score: 2	3 to 5	0.074	—	2.35 to 2.4
Reliability					
Internal consistency	0.74 to 0.93	0.6 to 0.9	—	0.92 to 0.96	0.94 to 0.96
Test-retest reliability	0.60 to 0.81	0.5 to 0.95	0.63 to 0.8	0.88 to 0.93	0.80 to 0.92
Practical Aspects					
Completion time (in minutes)	5 to 12.5	19 to 30	3	10	1.4 to 1.9
Available languages	120	21	22	4	>40
Cost	Not publicly available	€500 to 800+	Free	Free	Free

[a]Data from Hays RD, Morales LS: The RAND-36 measure of health related quality of life. *Ann Med* 2001;33(5):350-357; Angst F, Aeschlimann A, Stucki G: Smallest detectable and minimal clinically important differences of rehabilitation intervention with their implications for required sample sizes using WOMAC and SF-36 quality of life measurement instruments in patients with osteoarthritis of the lower extremities. *Arthritis Rheum* 2001;45(4):384-391; Brazier JE, Harper R, Jones NM, et al: Validating the SF-36 health survey questionnaire: New outcome measure for primary care. *Br Med J* 1992;305(6846):160-164; Andresen EM, Rothenberg BM, Kaplan RM: Performance of a self-administered mailed version of the Quality of Well-Being (QWB-SA) questionnaire among older adults. *Med Care* 1998;36(9):1349-1360; Edelman D, Williams GR, Rothman M, Samsa GP: A comparison of three health status measures in primary care outpatients. *J Gen Intern Med* 1999;14(12):759-762.

[b]Data derived from Deyo RA, Patrick DL: The significance of treatment effects: The clinical perspective. *Med Care* 1995;33(4 suppl):AS286-AS291; de Bruin AF, de Witte LP, Stevens F, Diederiks JP: Sickness Impact Profile: The state of the art of a generic functional status measure. *Soc Sci Med* 1992;35(8):1003-1014; Andresen EM, Rothenberg BM, Kaplan RM: Performance of a self-administered mailed version of the Quality of Well-Being (QWB-SA) questionnaire among older adults. *Med Care* 1998;36(9):1349-1360; Edelman D, Williams GR, Rothman M, Samsa GP: A comparison of three health status measures in primary care outpatients. *J Gen Intern Med* 1999;14(12):759-762; Coons SJ, Rao S, Keininger DL, Hays RD: A comparative review of generic quality-of-life instruments. *Pharmacoeconomics* 2000;17(1):13-35.

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[e]Data derived from Rothrock NE, Kaat AJ, Vrahas MS, O'Toole RV, Buono SK, Morrison S, Gershon RC. Validation of PROMIS physical function instruments in patients with an orthopaedic trauma to a lower extremity. *J Orthop Trauma* 2019;33(8):377-383; *HealthMeasures* [Internet]. HealthMeasures: Transforming how health is measured. [cited 2020 June 23]. Available at: https://www.healthmeasures.net.

Table 3

Examples of Clinical Trials and Outcome Measurement in Orthopaedic Trauma

Study	Publication Year	Study Design	PICO Framework	Major Findings
Published Studies				
Bhandari et al[6] (Study to Prospectively Evaluate Reamed Intramedullary Nails in Patients with Tibial Fractures [SPRINT])	2008	Multicenter randomized controlled study	Cohort: 1,319 adults with tibial shaft fracture Intervention: Reamed nailing Comparator: Unreamed nailing Outcomes: • Revision surgery within 1 year • SF-36, SMFA, HUI scores • Tibial knee pain	• No overall difference in revision surgery rate • Lower rate of revision surgery for closed fractures managed with reamed nailing • Trend toward lower rate of revision surgery for open fractures with unreamed nailing
Bosse et al[5] (Lower Extremity Assessment Project [LEAP])	2002	Multicenter prospective observational cohort study	Cohort: 569 adults with severe open lower extremity injury Intervention: Limb salvage Comparator: Amputation Outcomes: • SIP score • Limb status • Rehospitalization	• No overall difference in SIP scores at 2 years • Lower SIP scores for foot and ankle injuries with flap or ankle fusion • High level of long-term disability • Self-efficacy a strong predictor of ultimate outcome
Rangan et al[37] and Corbacho et al[38] (PROximal Fracture of the Humerus Evaluation by Randomization [PROFHER])	2015, 2016	Economic analysis in addition to pragmatic multicenter randomized clinical trial	Cohort: 250 adults with acute displaced proximal humerus fractures Intervention: Surgery (ORIF or arthroplasty) Comparator: Nonsurgical treatment with sling Outcomes: • Oxford Shoulder Score • EQ-5D score • Direct costs of care	• No difference in shoulder scores at any time point • Higher complication rate with surgery • Higher cost and lower quality of life with surgery

HUI = Health Utilities Index, ORIF = open reduction and internal fixation, PICO = population-intervention-comparison-outcome, SF-36 = 36-Item Short Form, SIP = Sickness Impact Profile, SMFA = Short Musculoskeletal Function Assessment

(2) computer adaptive testing for specific domain; or (3) profile option where all items are completed for a specific domain. Item response theory and computer adaptive testing are two key features that affect the administration of PROMIS and distinguish it from common legacy instruments for measuring HR-QOL that are static. In item response theory, the response to a question determines the next question to be administered. This feature increases the efficiency and accuracy of the final score; by using computer adaptive testing, PROMIS can achieve the same validity and reliability as conventional techniques through fewer questions. In patients with orthopaedic trauma, the testing time for the PROMIS physical function domain was 44 seconds compared with 599 seconds for the SMFA.[40] Furthermore, there were no ceiling effects for PROMIS compared with a 14% ceiling effect for the SMFA. (Ceiling and floor effects occur when an instrument cannot differentiate individuals at the high [ceiling] or low [floor] end of the scale.) Because PROMIS uses item response theory to choose each question based on the response to the preceding question, it can focus on demanding activities for high-functioning subjects and

thereby reduce the ceiling effect. The ceiling effect has been particularly problematic in generic instruments applied to patients with an upper extremity injury.[32] PROMIS was found superior to the Disabilities of the Arm, Shoulder and Hand score, which was designed for patients with upper extremity injury.[41] Despite both theoretical and practical advantages, PROMIS measures continue to lag behind legacy instruments for the assessment of quality of life in orthopaedic trauma studies. In a recent review of 319 orthopaedic trauma clinical studies published between 2014 and 2018, PROMIS measures including PROMIS Physical Function, Pain Interference, and Upper Extremity Function were used in only 7 studies (2%).[42] It is likely that improved familiarity and interpretability of PROMIS measure, through initiatives such as PROsetta Stone (www.prosettastone.org) that aim to improve comparability with legacy instruments, will increase their adoption in both clinical and research settings.

Economic Analysis

In conjunction with the expanding emphasis on improving quality in health care by measuring PROs, there is pressure to reduce costs. In the future, surgeons will increasingly need to become familiar with the nomenclature of economic analysis and the quantitative research methods used to estimate the value of medical interventions across the spectrum of health care. Cost analysis is an increasingly important part of comparative effectiveness research and accompanies many large prospective studies in orthopaedic trauma care as well as other areas of medical practice.

Cost-Minimization Analysis

A simple comparison of the total cost of two interventions is called a cost-minimization or cost analysis. This type of study is appropriate if the clinical benefits of each treatment strategy are not significantly different. In this uncommon situation, the cost-minimization study design is straightforward and may inform a subsequent, more complex economic analysis. An example would be comparing the cost of two implants that are believed to result in an equivalent clinical outcome.

Cost-Effectiveness Analysis

Cost-effectiveness analysis (CEA) attempts to estimate the cost of a given healthcare intervention to produce a unit of health benefit.[43] Usually the results of a CEA are quantitatively expressed as the ratio of the cost of the intervention to some term that quantifies the benefit. The numerator always contains cost, whereas the denominator can be any outcome of interest. For example, a CEA could report the cost per life saved or the cost per complication averted. The disadvantage of this method is that the more specific the outcome chosen for the denominator, the more difficult it is to make comparisons across studies.

Cost-Utility Analysis

Under the umbrella of CEA is cost-utility analysis, which is a more specific type of economic analysis. Rather than a clinical outcome, the denominator of the ratio is utility, which expresses the societal preference for a health state ranging from 1 (equating to perfect health) to 0 (equating to death).[43] For example, a patient with severe osteoarthritis might have a utility of 0.7, and a patient with a spinal cord injury might have a utility of 0.3. By multiplying the utility of the health state with the number of years spent in the health state, quality-adjusted life years can be calculated. This method makes it possible to compare in a single metric interventions that prolong life with those that have more effect on quality of life. Quality-adjusted life years are the recommended and most commonly used value for the denominator of a cost-utility analysis.[44]

The primary outcome in a cost-utility analysis is the incremental cost-effectiveness ratio (ICER). The ICER is a ratio of the incremental cost of the intervention to the comparator and the incremental utility of the intervention relative to the comparator:[43]

$$\text{ICER} = \frac{\text{Cost}_{\text{Intervention}} - \text{Cost}_{\text{Comparator}}}{\text{Utility}_{\text{Intervention}} - \text{Utility}_{\text{Comparator}}}$$

It is crucial that studies include a baseline comparison to report an accurate ICER, rather than assuming that the baseline cost and utility are 0. Even a do-nothing approach has a cost and health effect on the population and therefore should be estimated as the comparator. In fracture healing studies, the comparator typically is nonsurgical treatment, which often is associated with the cost of clinic visits for casting and radiographs and will have an outcome that is almost invariably better than 0, which is equivalent to death.

Cost-Benefit Analysis

Unlike a CEA or cost-utility analysis, in which the cost and benefit are kept separate by using a ratio, a cost-benefit analysis or benefit-cost analysis converts both cost and benefit into monetary units. The result can be expressed as the net monetary benefit (NMB). A net monetary benefit higher than 0 indicates that the strategy will save money, whereas a net monetary benefit lower than 0 indicates that the strategy will lose money. The challenge of this approach is that ethical issues arise when a monetary value is assigned to human life or health benefits. Therefore, benefit-cost analysis is infrequently used in health care. The principal advantage of this approach at

a governmental level is that it can be used to compare programs in other sectors such as education or environment relative to healthcare programs.

SUMMARY

The PICO framework can be a helpful tool for designing and interpreting high-quality clinical outcome studies. The first step in designing a study is to specify the target population. The treatment strategies in a comparative study can be assigned at random or in an observational manner. The risk of confounding bias is more likely in an observational study because the treatment groups may be unequal and therefore have a different prognosis for the measured outcome. Outcome measurements can be surgeon or patient reported; PROs increasingly are emphasized in healthcare research. Dynamic instruments implementing item response theory and using computer adaptive testing were developed during the past decade. Alternatively, performance-based outcomes have the benefit of objectively measuring functions directly affected by interventions used to treat patients with orthopaedic trauma conditions. Research into the cost of treatments as related to other outcomes and health utility metrics allows the monetary value of treatments and services to be estimated and will increasingly drive medical decision making in a resource-constrained environment.

KEY STUDY POINTS

- The PICO framework is a useful tool for constructing and interpreting research studies.
- The process of randomization, used to create two equivalent groups of patients for a study, minimizes the effect of confounding bias. Several methods are available to reduce bias in observational studies, but none of them can eliminate the influence of unmeasured confounding variables.
- Generic outcome questionnaires measure overall HR-QOL. Disease-specific outcome questionnaires may be more responsive but cannot be used for comparison across disease states.
- The PROMIS instruments use computer adaptive testing to reduce administration time and improve accuracy compared with traditional questionnaires. The use of PROMIS in orthopaedic surgery remains limited.
- The results of a CEA often are reported as the ICER, which can be used to estimate the cost per incremental improvement in health care related to one intervention compared with another. This result commonly is reported as cost per quality-adjusted life year.

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CHAPTER 2

Delivery of Orthopaedic Trauma Care

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ABSTRACT

Trauma systems worldwide provide varying levels of care, with gaps in coverage in every global region, including the United States. The number of orthopaedic-related emergency department visits is increasing at the same time as multiple legislative events reduce access to specialty orthopaedic care in the United States. The number of trauma centers continues to increase, additionally straining the orthopaedic surgeons providing coverage at these institutions. Novel models for orthopaedic emergency coverage have been developed to provide care, with varying results. The orthopaedic trauma surgeon is an integral part of the system that provides education and quality improvement while participating in the leadership required to orchestrate care during mass casualty incidents.

Keywords: access to orthopaedic trauma care; acute care orthopaedics; orthopaedic call coverage; trauma systems

INTRODUCTION

More than 50% of all hospitalized trauma patients in the United States have musculoskeletal injuries that could be limb threatening or life threatening or could result in substantial functional impairment. More than 200,000 adolescents and adults younger than 65 years are hospitalized annually in the United States because of lower extremity fractures.[1] The global injury burden is disproportionately high, where in some low-income and middle-income countries this approaches 90%.[2]

With this large number of acute orthopaedic injuries comes a need for access to an appropriate level of orthopaedic care. Patients flow through a rapidly evolving medical system following a complex geopolitical pathway to their ultimate destination, which may be a small community setting, a level I trauma hospital in an academic setting, or the many options in between.

PATIENT ACCESS TO EMERGENCY CARE

Emergency department crowding represents a global crisis that can affect the quality and access of health care.[3] The number of patient visits to emergency departments across the United States continues to rise at a concerning rate. According to the Centers for Disease Control and Prevention, 119 million emergency department visits were made in 2006, and 139 million visits were made in 2017, representing a 16% increase over 11 years.[4] Meanwhile, the total number of acute hospitals has decreased steadily between 1975 and 2015. The strain on the medical system and on orthopaedic surgeons in particular becomes more tangible, and some call arrangements that worked in the past may no longer be sufficient to provide orthopaedic coverage. Emergency departments report a varying availability of on-call orthopaedic coverage,[5] with only approximately one-half of those surveyed reporting adequate coverage on weekends and at night. The reasons cited for lack of coverage include the interruption of family life and lifestyle, inadequate compensation, and the

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disruption of the elective orthopaedic practice.[6] In many regions, traditional call panels have been supplanted by coverage solutions that match the current trends and needs to provide acute orthopaedic surgical care across the United States. At the same time, as changes in healthcare access in this country are evolving, the availability of orthopaedic specialists is in decline.

THE PATIENT PROTECTION AND AFFORDABLE CARE ACT

Access to orthopaedic specialty care in the outpatient setting varies by region depending on many factors, including the density of providers, the geographic location, and patient health insurance status. The Patient Protection and Affordable Care Act, commonly called the Affordable Care Act (ACA), was signed into law in 2010.[7] The primary goal of the ACA is to reduce the financial barriers to health care for all US citizens. In 2017, a modification of ACA was passed, which came into effect in 2019. This eliminated the individual mandate requiring citizens to register and pay for insurance under the ACA, weakening the plan and resulting in a reduction of enrollment. The implications of this are not fully realized but will likely require an expansion of federal funding.[8] Unlike elective surgery with its requisite preauthorization process, trauma surgery does not have a protocol for insurance approval before intervention. Theoretically, if a higher percentage of the population is insured, trauma centers should benefit.

Massachusetts was the first state whose healthcare system instituted healthcare reform and served as a model for the ACA. After the introduction of healthcare reform in Massachusetts, the three level I trauma centers in Boston saw a 40% reduction in the risk of treating uninsured individuals. Additionally, uncompensated care decreased from 17% to 11.5%. Mortality rate in the state has declined since the implementation of healthcare reform. These reductions were most evident in the poorest counties.[9]

To contain healthcare costs, the ACA aims to shift to value-based reimbursement. The goal is to deliver the highest quality of care at the lowest possible cost, meanwhile improving access for minorities. The model developed to achieve this goal is the accountable care organization (ACO), which is a network of physicians and hospitals created to share the burden of delivering care for a group of patients. In the time since implementation of ACOs, for many Americans, no detectable reduction in access to surgical treatment was found, although there remains a disparity between minorities and nonminorities regarding access to surgical care within and outside of ACOs.[10]

Additionally, the ACA shifts the burden of collecting and reporting quality indicators to physicians and incentivizes physicians and hospitals to comply with Medicare guidelines through the meaningful use of electronic health records. The ACA attempts to fundamentally shift health care from a volume-centered payment system to a patient-centered, outcome-driven system. This paradigm shift could affect orthopaedic surgeons greatly, particularly those caring for patients who are traumatized. Patients with trauma have considerable variability in injury mechanisms and patterns. Reporting quality indicators will be the responsibility of physicians. The most appropriate trauma care may not be within the geographic location of a patient's ACO, which will make outcome reporting challenging for the practitioner.[11]

The ACA has resulted in an expansion of Medicaid services in most states. With this shift has come a relative shortage of specialty providers, including orthopaedic surgeons, who have not enrolled as providers in some of these expanded Medicaid plans. Therefore, when patients are referred to an orthopaedic specialist for an acute or subacute injury, their insurance status may still be a barrier to access.[12] This circumstance creates a cycle in which injured patients must return to the emergency department, increasing the number of visits to the emergency department and ultimately increasing costs. These patients are generally more successful in obtaining a specialty referral when referred directly from an emergency department, partly because of contractual obligations between hospitals and orthopaedic call groups and partly because of laws ensuring that emergency treatment does not depend on insurance status.[13]

THE EMERGENCY MEDICAL TREATMENT AND ACTIVE LABOR ACT

Emergency department visits in the United States have risen steadily since patients were guaranteed medical attention under the Emergency Medical Treatment and Active Labor Act in 1986. This act requires emergency care physicians to evaluate and stabilize all patients regardless of their ability to pay, and hospitals must provide specialist care or arrange transfer when specialist care is unavailable. This requirement creates the potential for abuse because hospitals that do not have continuous specialty coverage could transfer patients based on their inability to secure an orthopaedic surgeon. Even when a particular hospital has busy and active orthopaedic surgeons, the emergency department is forced to transfer a patient to a facility with guaranteed coverage if the orthopaedic surgeons are not required through hospital bylaws to take emergency call and refuse to evaluate a particular patient. This arrangement has been shown to preferentially occur with underinsured patients and minorities, who become more likely to be designated as having an emergency medical condition for the purpose of transfer.[6,14] Transfers of patients even occur between

level I centers when specialty care is not available or not capable of managing the problem, although these core specialties are actually required for trauma level I and II designations.[15]

ALTERNATIVE SOLUTIONS FOR ORTHOPAEDIC CALL COVERAGE

More orthopaedic emergencies are occurring, but fewer orthopaedic surgeons are willing to take call.[6] If this trend continues, general surgeons may be enlisted for certain emergency orthopaedic call coverage. The American Association for the Surgery of Trauma has identified a shortage of coverage not only in orthopaedic surgery but also in general surgery, creating subspecialty fellowship training within general surgery called acute care surgery. [16] In addition to the components of general surgical acute care, which include emergency surgery, critical care surgery, and trauma surgery, criteria exist for fellowships that include elective training in select basic orthopaedic procedures. Currently, 25 American Association for the Surgery of Trauma–accredited fellowships are available in the United States. The acute care surgery fellowship curriculum recommends learning techniques of emergency extremity surgery, including vascular repair, fasciotomies, débridements, and amputation.

Similar to adaptation of physicians to internal medicine hospitalist and subsequently general surgery surgicalist services, the concept of the orthopaedic hospitalist has developed and grown because hospitals need consistent care and have hence engaged physicians and groups willing to provide continuous coverage for all inpatient needs.[17] The predominant subspecialty group providing this service in the United States is the orthopaedic traumatologist, partly because of the need for transfers from community hospitals. This revolves around complex hip and fragility fractures, periprosthetic fractures, nonunions, and osteomyelitis, all of which are within the technical scope of a traumatologist. Although still outnumbered by traditional call panels, these orthopaedic hospitalist services are gaining in popularity across the country.[18] When comparing hip fracture outcomes, efficiency gained with orthopaedic hospitalist coverage appears to shorten hospital length of stay.[19]

The response to this development within the medical community is mixed, but hospitals and emergency department providers are satisfied with the continuity of coverage. The orthopaedic trauma community is divided but generally supportive of this paradigm shift in treatment. Some surgeons even assert that the experienced trauma surgeon is being replaced with young inexperienced surgeons at the expense of not only the experienced surgeons but also the surrounding community.[20,21] As this evolution occurs, orthopaedic surgeons need to be more active in local hospital administration to help establish the quality metrics that emphasize the favorable effect of the experienced physician on the quality of patient care.

TRAUMA SYSTEM MODELS

Trauma care worldwide varies greatly from region to region. The disparities between emerging economies lead to significantly worse outcomes than developed nations.[22] In late 2018, the World Health Organization launched a Global Emergency and Trauma Care Initiative, to assist in with education and to rapidly increase capacity to treat, with a goal of saving millions of lives worldwide over the next 5 years.[23]

Latin America has coordinated trauma care in its most populous countries, with high standards set to provide the best care. However, the consistency of delivery in Latin America is poor, with rural areas lacking care and funding of trauma systems dependent on the labile economic forces driving growth in these regions. Focus on trauma education and registries is bound to improve the coordination of care in this region.[22] The European system of trauma is varied as well, without a unifying single system across various countries.[24] The overall quality of care delivered is high because of high caliber of trauma centers distributed across Europe. Like North America and worldwide, despite a high level of care and standards, there exist areas within Europe that lack specialty care in trauma, leaving gaps in coverage.

China and India are the two most populous countries, each with more than one billion inhabitants. Neither country has a formalized trauma system, and hence, the mortality from trauma, specifically road traffic accidents, is the highest in the world.[25] Each country has the ability to provide high-level orthopaedic surgical care, although this varies regionally and especially varies from rural to urban populations. Hospital crowding and resources are limited in many areas. Trauma hospitals are present regionally, and each country has devoted significant increases in allocation of resources to improve and coordinate trauma care. Trauma registries are not yet coordinated in either country, although plans exist to expand data collection, education, and research.

Like other regions globally, trauma hospitals in the United States were created initially out of need, providing a loose network of centers spread out geographically to meet the demands of patients requiring emergency care. Because the number of trauma facilities has grown over the decades, there remains a lack of standardization, with some hospitals verified by the American College of Surgeons (ACS) Committee on Trauma, whereas other hospitals operate independently of that credential. With the disjointed nature of the trauma system in North America, there remains substantial opportunity for optimization

of trauma care. A major goal of the creation of a trauma center network is to provide consistent level I trauma care within a 60-minute transport time. Although the number of trauma centers in the United States has increased dramatically, most are concentrated in urban settings, having little effect on transport time. At the same time, some remote rural areas of the country still lack basic 911 emergency coverage.[26] Canada has a similar problem with large distances in many parts of their country, although very rural areas often still manage to deliver patients to trauma centers within a target of 60 minutes. Response times in Canada are, in some regions, faster in rural outlying areas than in urban centers.[27]

To become a trauma center in the United States, hospitals purport a need and work toward the goal within their local, county, and state medical societies. Each state assigns a designation level depending on the needs of the locale and the services the hospital is capable of providing. At least 1,100 designated trauma centers exist in the United States.[18]

The ACS Committee on Trauma has established high standards for trauma centers. Only after these standards are met through the ACS process does a hospital become a verified trauma center. Currently, more than 530 ACS-verified trauma centers exist. Such level I trauma centers require orthopaedic trauma care to be overseen by an OTA-approved and fellowship-trained orthopaedic traumatologist.[1]

As the number of trauma centers continues to grow, so too does controversy over whether the recently established centers are designated and verified in locations that most appropriately serve the needs of the patient and the trauma community. The allocation of trauma centers should be based on the needs of the population rather than on the needs of individual healthcare organizations or hospital groups.[28-30]

In certain urban environments, large healthcare organizations have created trauma centers for a variety of reasons. They usually cite patient need, but may be motivated instead by issues of secondary gain, including a reduction in the number of patients with trauma they would lose in transfer and an increase in the number that they repatriate back into their medical systems. These organizations receive a share of public funds allocated for trauma care. Within orthopaedic trauma, it has been shown that a dedicated trauma center brings considerable downstream revenue to the hospital through surgical care and the many ancillary services required during the course of such care.[31,32]

Given the large numbers of ACS level II and III trauma hospitals in urban settings, two phenomena have been observed. First, the central level I center sees fewer patients with trauma, adversely affecting their training programs and reducing the number of patients available to residents and fellows. Second, emergency department throughput may be improved by the shift to other nearby centers, reducing the treatment time for injured patients in that center. In the newly established level II and III centers, similar opposing phenomena exist. Bringing a severely injured patient to a trauma center not fully prepared for complex orthopaedic or other subspecialty care necessitates transfer to a nearby level I or II hospital better equipped for these patients. The outcome for the patient can potentially be influenced for the better.[33-35] Having outlying trauma centers still accomplishes a reduction in the initial treatment time, which is beneficial for most injuries. Careful triage in the field before transport can reduce the number of second transports. Most patients are injured close to home or work, and the effect on families is reduced when the hospitalized patients are nearby. Families can offer more support to the injured patient without having to travel long distances, which could preclude their ability to provide that support. With the existence of additional level II and III hospitals, patients often can be repatriated back to the lower level trauma centers for secondary orthopaedic and other procedures as required later, when the patient is stable, thereby reducing the burden on the level I tertiary care centers.

QUALITY IMPROVEMENT AND EDUCATION

The ACS Committee on Trauma requires each trauma program to demonstrate a continuous process of monitoring, assessment, and management directed at improving care.[1] This process is called the Performance Improvement and Patient Safety (PIPS) Program. PIPS includes a written plan and an operational data system that has the goal of improving the six aims of patient care: safe, effective, patient centered, timely, efficient, and equitable. The system includes regular internal peer review and regular external review and integration with the local and regional trauma system efforts. PIPS uses a model called the Continuous Process of Performance Improvement. The steps involved begin with recognizing an area of improvement through data collection and collation, assessing the area through analysis, and then improving the area through modification and instruction. Trauma centers must be able to demonstrate a PIPS system, which requires internal and external oversight, local and regional integration, the authority to effect change, a trauma registry to collect data, and assurance that specific PIPS core measures are met within the trauma center. Quality improvement at trauma centers is bound inextricably to the quality of care that is delivered to patients, and it requires a dedicated system to make improvements effectively while minimizing bureaucratic interference. To that end, Trauma Quality Improvement Program is a nationwide database managed by the ACS where hospitals can compare themselves with

similar programs across the United States. This program enables the hospital systems to closely examine and make clinical changes in their practice. It has a set of best practice guidelines in the management of orthopaedic trauma detailing many of the commonly encountered orthopaedic emergencies, which are updated regularly.[36-38]

The individual orthopaedic surgeons integrated into a hospital's trauma system must participate in these programs because it is necessary for all subspecialties to improve care, not simply for the trauma coordinators and medical directors to review. Continuing education beyond completion of training is a career-long requirement for licensure and the maintenance of board certification and hospital privileges, but it must include education in trauma care to satisfy the requirements of the ACS and PIPS.

An emerging facet of medical education for orthopaedic trainees is a growing number of orthopaedic trauma fellowships that offer global health opportunities. Seven percent of responding orthopaedic trauma fellowships and 12% to 32% of orthopaedic residency programs offer opportunities for international health electives. Benefits of such opportunities are widely recognized and include a better understanding of international trauma needs, improved recognition of optimizing resources, improved clinical skills, and lasting international professional relationships.[39]

DISASTER AND MASS CASUALTY PLANNING

According to the ACS, the surgical community has an obligation to be actively involved in disaster and mass casualty planning at all levels, including those of the local, state, and federal government. As a result, trauma centers are required to have hospital disaster plans and biannual drills that integrate local hospitals and emergency services. Hospitals must exert substantial effort to develop these systems and to coordinate drills, but they are required to be aggressive regarding disaster and mass casualty management because disasters are not uncommon.[40]

The declaration of a disaster or mass casualty incident (MCI) is based on resources. Although the magnitude of an individual event may not be high, designating an event as a disaster or MCI indicates that the local services are overburdened and require more resources.[41] An MCI declaration signifies that the number, severity, or diversity of injuries overwhelms the local medical resources. Lower level trauma facilities will be overwhelmed sooner than a larger facility. The frequency with which these events occur highlights the importance of trauma centers having a complete and rehearsed plan to cope with disaster and mass casualties.

When disasters and MCIs occur, the trauma center is an integral component of the system. Trauma centers are mandated to have a disaster plan and to ensure that the most good can be brought to the greatest number of people through communication, cost containment, and management. If the availability of acute care and trauma orthopaedic surgeons declines, the already challenging task of providing proper care in this environment will be strained even further.

SUMMARY

The delivery of orthopaedic trauma and acute care globally and in the United States is complex. The evolution and expansion of high-quality trauma centers require surgeons to adapt and function in an evolving system to deliver excellent patient-centered care to their community. Orthopaedic trauma surgeons are charged with becoming experts in complex data gathering processes, internal and external reviews and oversight, cost-containment strategies, and disaster planning with local, state, and federal governmental branches. It is incumbent on all orthopaedic surgeons to do their part in serving their communities by cooperating with the trauma systems, while continuing to refine and develop their clinical skills as acute care orthopaedic surgeons. All orthopaedic surgeons must receive and maintain adequate training to remain proficient in the delivery of acute care and to develop an understanding of their role in the trauma systems in which they practice. It is the physician's responsibility to serve the needs of the community in addition to the needs of the medical practice. Patients deserve expert care regardless of who is on call.

KEY STUDY POINTS

- Patient access to emergent orthopaedic care is a dynamic entity, limited in some areas by physician call panel availability.
- The Patient Protection and Affordable Care Act of 2010 (and its individual mandate repeal) will affect access to orthopaedic care in the United States. The costs of emergency orthopaedic care may decline because fewer patients are expected to be uninsured, although access to nonurgent orthopaedic trauma care may remain limited unless additional orthopaedic surgeons enroll as Medicaid providers.
- The establishment of networked trauma systems has evolved, and additional designated trauma centers are being added yearly. Changes in the distribution of new trauma centers should be based on geospatial need and not on health system financial incentives. Trauma center development may improve the coordination of disaster planning and mass casualty treatment if orthopaedic trauma surgeons become involved in leadership at the local hospital level.

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14. Broman KK, Phillips S, Hayes RM, et al: Insurance status influences emergent designation in surgical transfers. *J Surg Res* 2016;200(2):579-585.

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15. Jones MD, Kalamchi LD, Schlinkert AB, et al: Are all trauma centers created equal? Level 1 to level 1 trauma center patient transfers in the setting of rapid trauma center proliferation. *J Trauma Acute Care Surg* 2020;89(5):920-925.

    Over a 5-year period, the authors reviewed transfers between level I centers. The causes for transfer involved lack of specialty coverage or level of care beyond capability, usually neurosurgical, with significant financial effect on the hospital and patient. Level of evidence: IV.

16. Duane TM, Dente CJ, Fildes JJ, et al: Defining the acute care surgery curriculum. *J Trauma Acute Care Surg* 2015;78(2):259-263.

17. Wachter RM, Lee G: Zero to 50,000-the 20th anniversary of the hospitalist. *N Engl J Med* 2016;375(11):1009-1011.

The hospitalist was first described in the mid-1990s and over the past twenty years has become the largest internal medicine subspecialty in the United States and the largest medical specialty other than general internal medicine. The rise of hospitalist medicine has dominated inpatient care, where efficiencies and patient outcomes have caused other specialties, including orthopedic surgery, to adopt the hospitalist model for themselves. Level of evidence: VII.

18. Agnew SG, Warren BJ: Orthopaedic trauma career and employment horizons: Identification of career destinations and opportunities. *J Orthop Trauma* 2012;26(suppl 1):S18-S20.

19. Bracey DN, Kiymaz TC, Holst DC, et al: An orthopedic-hospitalist comanaged hip fracture service reduces inpatient length of stay. *Geriatr Orthop Surg Rehabil* 2016;7(4):171-177.

    A retrospective-prospective cohort study compared length of stay between standard and orthopedic/hospitalist comanaged patients, finding a shorter length of stay and time to surgery for the comanaged patients, without negative impact on 30 day mortality. Level of evidence: IV.

20. Hill A, Althausen PL, O'Mara TJ, Bray TJ: Why veteran orthopaedic trauma surgeons are being fired and what we can do about it? *J Orthop Trauma* 2013;27(6):355-362.

21. Bray TJ: Orthopaedic traumatology: More than a "surgicalist" – Modified with permission from American Academy of Orthopaedic Surgeons. AAOS now 2013, volume 7, number 6. *J Orthop Trauma* 2013;27(8):425-427.

22. Rojas LGP, Roberto LCE, Manuel PAM, et al: Latin America trauma systems – Mexico and Brazil. *OTA Int* 2019;2(S1):e020.

    Mexico and Brazil comprise the two largest countries in Latin America. Their trauma systems have certain issues in common, mainly challenges with resources and funding. The Mexican system has lack of properly trained ambulance and prehospital care in many areas. Brazil has a high-quality trauma and healthcare system within São Paulo, but because geographic distances are so large, much of the country struggles to attain the level of care that can be provided in its largest city. Level of evidence: V.

23. WHO Link: World Health Organization Global Health Initiative: Emergency Care. Available at: https://www.who.int/emergencycare/global-initiative/en/.

24. Chesser TJS, Chris M, Keith W, et al: Development of trauma systems in Europe – Reports from England, Germany, The Netherlands, and Spain. *OTA Int* 2019;2(S1):e019.

    The authors describe the individual systems within these countries. England has a strong prehospital care and transport system. Germany and the United States have many parallels in their trauma organization, including an organization for optimization of resources. The Netherlands has had a later entry into the organized trauma system, although they appear to have a well-functioning system with many smaller regions. Spain offers good health care free to all, and despite some inefficiency, they have one of the lowest trauma mortality rates in Europe. Level of evidence: VII.

25. Babhulkar S, Ashutosh A, Devashish B, et al: Trauma care systems in India and China: A grim past and an evolving future. *OTA Int* 2019;2(S1):e017.

    The two most populous countries are without integrated nationwide trauma systems. China has high-quality care in large population nuclei, but transport time and hence care and outcomes sustain in the isolated rural areas. China has no comprehensive trauma registry, although they are making rapid progress in implementation. India has a multitiered hospital system where the university level trauma (level I) hospitals manage all injuries with all subspecialties represented. Level II hospitals handle some of these injuries, whereas level III hospitals have no infrastructure for trauma. The largest contributor to death is road traffic accidents, and it is in this realm that India's leadership is seeking to improve safety, which in turn will decrease the burden on their overwhelmed medical system. Level of evidence: VII.

26. Institute of Medicine: *Preparedness and Response to a Rural Mass Casualty Incident: Workshop Summary*. Washington, DC, The National Academies Press, 2011.

27. Lundy DW, Edward H, Alex JA, et al: Trauma systems in North America. *OTA Int* 2019;2(S1):e013.

    The authors describe the genesis and current status of trauma systems in Canada and the United States, with many similarities such as guidelines for establishment of their trauma system, although neither country has a unified nationwide system. The United States has the ACS that verifies trauma centers, but not all centers seek verification. Some states are beginning to require ACS verification for funding. Canada has provincial differences, and each province has large geographic areas that require air transport for patient transfer. Quebec is the only province that does not fund the use of helicopters for air transport. Level of evidence: VII.

28. Horst MA, Gross BW, Cook AD, Osler TM, Bradburn EH, Rogers FB: A novel approach to optimal placement of new trauma centers within an existing trauma system using geospatial mapping. *J Trauma Acute Care Surg* 2017;83(4):705-710.

    This epidemiologic study gathered data from trauma centers in Pennsylvania, determining that additional coverage based on density of trauma incidents in a geospatial model would necessitate fewer new trauma centers if strategically placed, rather than based on the current system that prioritizes other factors and not proximity to existing trauma centers. Level of evidence: III.

29. Branas CC, MacKenzie EJ, Williams JC, et al: Access to trauma centers in the United States. *J Am Med Assoc* 2005;293(21):2626-2633.

30. American College of Surgeons: Statement on trauma center designation based upon system need. *Bull Am Coll Surg* 2015;100(1):51-52. Available at: http://bulletin.facs.org/2015/01/statement-on-trauma-center-designation-based-upon-system-need/. Accessed February 8, 2016.

31. Althausen PL, Coll D, Cvitash M, Herak A, O'Mara TJ, Bray TJ: Economic viability of a community-based level-II orthopaedic trauma system. *J Bone Joint Surg Am* 2009;91(1):227-235.

32. Kleweno CP, O'Toole RV, Ballreich J, Pollak AN: Does fracture care make money for the hospital? An analysis of hospital revenues and costs for treatment of common fractures. *J Orthop Trauma* 2015;29(7):e219-e224.

33. Demetriades D, Martin M, Salim A, Rhee P, Brown C, Chan L: The effect of trauma center designation and trauma volume on outcome in specific severe injuries. *Ann Surg* 2005;242(4):512-517.

34. Caputo LM, Salottolo KM, Slone DS, Mains CW, Bar-Or D: The relationship between patient volume and mortality in American trauma centres: A systematic review of the evidence. *Injury* 2014;45(3):478-486.

35. Galanis DJ, Steinemann S, Rosen L, Bronstein AC, Biffl WL: Rural level III centers in an inclusive trauma system reduce the need for interfacility transfer. *J Trauma Acute Care Surg* 2018;85(4):747-751.

    In this review before and after several rural level III centers were established in a level I catchment area, the number of interfacility transfers decreased by 32% without a resultant increase in morbidity and mortality rates. The authors conclude that coordinated, geographically located verified level III centers can serve the population and reduce unnecessary patient transfers. Level of evidence: III.

36. Miller AN, Kozar R, Wolinsky P: Feasibility of and rationale for the collection of orthopaedic trauma surgery quality of care metrics. *J Am Acad Orthop Surg* 2017;25(6):458-463.

    The ACS has established metrics for benchmarking quality of orthopaedic trauma treatments, including open fracture and femur shaft treatment protocols. The system of collection is early in the process and shows promise to enable evaluation and comparison of quality metrics between institutions. As the process matures and participation becomes robust, this should allow for the evaluation of specific protocols as well as individual system performances and outliers. Level of evidence: VI.

37. Blackmore AR, Leonard J, Madayag R, Bourg PW: Using the trauma quality improvement program metrics data to enhance clinical practice. *J Trauma Nurs* 2019;26(3):121-127.

    The authors describe their experience in implementing Trauma Quality Improvement Program data analysis to drill down and reveal areas where clinical practice could improve, such as in hip fractures, urinary tract infections, and deep vein thrombosis. This system can be used not only as a benchmark comparator but also for individual institutional improvement.

38. ACS TQIP-Best Practices in the Management of Orthopaedic Trauma. https://www.facs.org/-/media/files/quality-programs/trauma/tqip/ortho_guidelines.ashx.

    The ACS Committee on Trauma established a panel of experts to evaluate the best practices in many pertinent topics of orthopaedic trauma. The document is replete with evidence-based recommendations with a robust bibliography. The document is updated and serves as a companion to the *Resources for Optimal Care of the Injured Patient*, also published by the ACS.

39. Shaw J, Siy A, Dahm J, Lins L, Simske N, Whiting P: Limited availability of global health opportunities in US orthopaedic trauma fellowship programs. *OTA Int* 2019;2(4):e031.

    The authors surveyed trauma fellowships in the United States for programs offering international health electives, with 7% offering this option. With the growing interest, additional programs plan to offer electives in the future. The benefits include collaborative working relationships between international institutions as well as personal satisfaction for those who participate. Barriers to participation are explored including host and sending institution issues. Funding, disruption of workflow pathways, and call coverage are some of the identified barriers. Level of evidence: VI.

40. Schenk E, Wijetunge G, Mann NC, Lerner EB, Longthorne A, Dawson D: Epidemiology of mass casualty incidents in the United States. *Prehosp Emerg Care* 2014;18(3):408-416.

41. Joint Commission Resources, Inc.: *Emergency Management in Health Care: An All-Hazards Approach*. Oak Brook, IL, Joint Commission Resources, 2012.