The Applied Mathematics of the Geriatric Trauma Evaluation

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It's tough to make predictions, especially about the future.

—Yogi Berra

If you asked a layperson to do a shift as an emergency physician, most patients treated would still be alive 1 week later. The majority of our patients don't have a life-threatening illness, and for those who do, it's usually pretty obvious. Of course the layperson would be horribly inefficient and wouldn't know what actual tests or medications to order, but most nonphysicians could at least do a reasonable job of identifying critically ill patients. But eventually the layperson would make some serious mistakes. Ectopic pregnancy, subarachnoid hemorrhage, pulmonary embolism, aortic dissection, and acetaminophen overdose are important to the practice of emergency medicine not simply because they can be lethal but also because sometimes their lethality isn't immediately obvious. These lethal conditions that can have subtle presentations are the focus of a lot of research and education in our field; these are the conditions that define our specialty.

Enter the geriatric trauma patient. It seems that not a month goes by without a meeting to review a case of an injured older adult who fell at home and presented quite innocuously to the emergency department (ED) but had serious injuries and a substantial delay in care. In a recent and fairly typical case, the patient was triaged as a level 3 (out of 5), placed in a back room, and not treated by a provider until an hour after ED arrival, at which point it was discovered that the patient was hypotensive. Eventually, it was determined that the patient was receiving an anticoagulant and had multiple rib fractures and a splenic laceration. After receiving blood products and operative treatment, undergoing pulmonary complications, and having a long ICU stay, the patient was eventually discharged to a rehabilitation facility. But when the case is reviewed to determine the triage error, there is no smoking gun. The blood pressure at triage wasn't low, or even kind of low; it was 150/80 mm Hg. The pulse rate wasn't high, or even kind of high; it was 74 beats/min. The patient wasn't screaming in pain or covered in blood. And the mechanism was a low-energy one that left no obvious external signs of injury.

Injured older adults are frequent exceptions to the rule in regard to indicators of life-threatening injuries: they can die after low-energy mechanisms, they can present without worrisome physiologic signs, and even "minor" injury patterns can result in poor outcomes. But is it sufficient to simply call this group an exception, or do we need an entirely different calculus for evaluating these patients?

In this issue of *Annals*, Kojima et al[1] present analyses of 12 years of data from the Japan Trauma Data Bank. Because this is Japan, more than half the sample is aged 60 years and older, providing a rich opportunity to examine both causes and outcomes of trauma in the elderly. (In Japan, 33% of the general population is aged 60 years and older, a level that will be met by China, Russia, and most of Europe and only approached by the United States by 2050.[2]) Not surprisingly, the authors found that for older adults, falls are the dominant injury mechanism and that older adults have relatively high rates of injuries to the pelvis and lower extremity. Curiously, head and chest trauma were common among older patients but not more common than in younger patients and progressively less common for the oldest old. But the most important data for emergency physicians are in the authors' Table 3, which shows the accuracy of 2 trauma scores for predicting inhospital mortality. The Injury Severity Score, which sums the squares of injury scores from 6 regions, and the Revised Trauma Score, which uses mental status, blood pressure, and respiratory rate, are both quite predictive of mortality in younger patients but much less predictive for older ones.[1]

These results add to a growing body of evidence that neither physiologic criteria nor vital signs nor injuries (once

identified) accurately predict mortality in older adults.[3,4] Although much of the research in this field has focused on inaccurate field triage of injured elderly in the out-of-hospital setting, triage at ED arrival is also imperfect for many of the same reasons. First, there is heterogeneity in the ability to survive injuries among older adults. If a 10-year-old falls 20 feet, the main factor to determine survival is how he or she lands. If an 80-year-old falls at any height, the factors that determine survival include not just how he or she lands but also bone strength, muscle mass, cardiovascular reserve, and use of anticoagulants. Although vulnerabilities in these factors increase with age, they do not do so linearly or consistently in all individuals. As a result, there are some 80-year-olds who are more resilient than some 65-year-olds. This thought experiment leads us to a conceptual diagram of the relationship between age and ability to survive injury (Figure), the main feature of which is that the confidence band widens with increased age.

Second, lethal injures in older adults do not consistently produce early physiologic changes. Because the relationship between cardiac output and blood pressure becomes less correlated with increasing degrees of atherosclerosis, older adults may maintain an elevated blood pressure even after significant hemorrhage. Furthermore, patients who have hypertension may be relatively hypotensive at 120/80 mm Hg, which is usually interpreted as a normal blood pressure. Similarly, patients receiving β-blockers are less likely to have an elevated pulse rate after a serious injury. A Glasgow Coma Scale (GCS) score less than or equal to 14 is immediately alarming in an injured young patient. In older adults, GCS score less than or equal to 14 increases sensitivity for identifying patients with a serious injury,[5] but because of the frequency of dementia and delirium, most clinicians let this finding roll past the trauma bay and
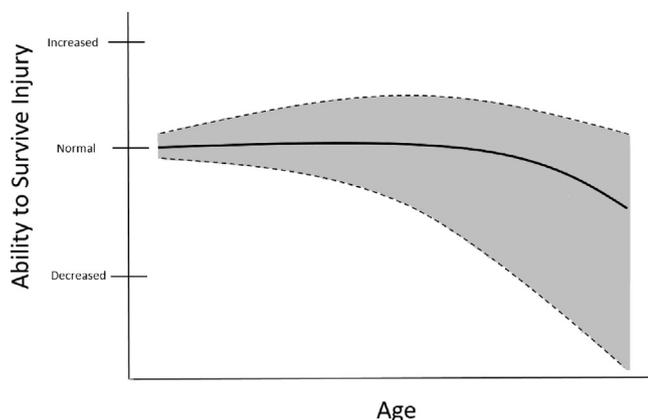
into the back hall. Thus, for older adults, the initial physiologic response to injury is often either falsely reassuring or actually abnormal but lost in a sea of abnormalities of unclear significance.

A third reason why it's hard to predict outcomes in injured older adults is that our measures and intuition often fail to recognize that many injured older adults have an underlying health trajectory that may have an outsized effect on outcomes. Among older patients who fall, it is common to learn from family that there has been a recent deterioration in health. The fall may be a manifestation of a brewing infection, an exacerbation of a chronic cardiopulmonary condition, or a troublesome combination of medications. Once a patient is put in the trauma category and heads down the well-worn pathway as prescribed by the Advanced Trauma Life Support algoritm, it's hard to see the concurrent medical trajectory. But failure to see both trajectories—one created by the injury and another by an underlying medical problem—makes it difficult to anticipate outcomes. For survivors, not addressing the patient's health trajectory means that we are not optimally preparing the patient to return home, contributing to poor recoveries after hospitalization or even after discharge from the ED.[6,7]

The implication for clinicians is that we need different criteria for identifying injured older adults at high risk for poor outcomes. We clearly can't rely solely on standard physiologic criteria or injury patterns. Other factors have been studied and implemented, including use of antiocoagulants,[8] lactate,[9,10] mechanism,[11] and alternative vital sign thresholds.[12,13] But although these factors have predictive value, an accurate out-of-hospital or ED-based triage instrument remains elusive. The largest studies to take on this challenge demonstrate sensitivities of approximately 93%, which means that 1 in 15 seriously injured older adults will be undertriaged.[12,14,15] One could in theory have a trauma alert for any injured patient aged 60 years or older and guarantee 100% sensitivity. But when modeled in the out-of-hospital setting and compared with traditional criteria, this yields approximately 60 false positives for each additional patient identified with a serious injury.[16]

Creative clinical approaches accompanied by research are needed. At one of our hospitals, injured older adults receive a physical examination by an emergency provider within 15 minutes of ED arrival to rapidly identify patients with concerning findings. At another of our hospitals, we are building a geriatric trauma center where all admitted older adults will be included in a clinical pathway through which geriatricians, trauma surgeons, physical therapists, and others work together to optimize the patients' recovery. Patients who have geriatric "high-risk" injuries, such as rib fractures, have specialized order sets to avoid common

Figure. Theoretical relationship between age and ability to survive injury. Dotted lines indicate upper and lower confidence intervals.

pitfalls (eg, poor pulmonary toilet, inadequate pain control, failure to mobilize the patient). As we improve our ability to identify and care for these patients, this knowledge will need to carry outward to the out-of-hospital setting, just as happened when triage criteria were developed from a model of the severely injured young adult.

The gift of Yogi Berra's tautology is that it forces us to reconsider the meaning of prediction: surely all predictions are about the future. Not exactly. Even when all the injuries are known for older adults, as is the case for the Injury Severity Score, we still can't predict mortality very well. No wonder it's hard to predict their future.

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