0022-5282/91/3108-1125$03.00/0
THE JOURNAL OF TRAUMA
Vol. 31, No. 8

Defining the Major Trauma Patient and Trauma Severity

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Criteria for defining the major trauma patient have been specified by physicians using Injury Patient Management Categories (PMCs), a computerized classification that can be used effectively with routinely collected discharge abstract data from non-trauma center hospitals as well as trauma centers. These criteria for major trauma not only include the more severe and complex single injuries, but also include criteria for identifying combinations of injuries that require tertiary level care. Major trauma patients identified as tertiary using PMCs are compared with existing and frequently used measures of injury severity such as AIS and ISS.

Analyses suggest that the Injury PMCs identify major trauma patients accurately and more specifically than other indicators of severity that are commonly used. In addition, unlike other measures that are generally limited to registries, PMC tertiary patient criteria differentiate major trauma patients at both trauma centers and non-trauma centers without additional data collection. Using this method thus facilitates trauma systems evaluation and patient outcome assessment.

Despite the recognized need for standardization in the definition of the major trauma patient for trauma systems evaluation and patient outcome assessment, there have, to our knowledge, been remarkably few advancements in this area. In 1980, the American College of Surgeons' Committee on Trauma[1] offered narrative descriptions for field categorization of trauma patients who require Level I trauma care. Such patients are, for example, those with two or more body system injuries, hypovolemic shock, uncontrolled hemorrhage, or severe injuries in various sites. Although these broad descriptions defining the major trauma patient were not intended as the basis of retrospective analysis, this type of specification must be operationalized and used retrospectively with large databases to evaluate trauma systems and assess patient outcomes.

Readily implementable methods (both prospective and retrospective) of defining trauma severity and identifying patients who require tertiary levels of care are important for a number of reasons. It seems clear, for example, that trauma patient characteristics and volume standards, in addition to the current assessments of facilities and staff capability, should be part of EMS planning and trauma center designation processes. Similarly, in a case-based payment environment such as Medicare's Prospective Payment System, it is critical to establish criteria to define the patients who are severely injured and who require the costly services of a specialized trauma center. Without such measures to differentiate the severity of trauma patient types, the comparative efficiency and cost effectiveness of trauma center hospitals will continue to be inadequately measured.

To address this need, in this research project we have defined criteria that can be readily used to identify the major trauma patient and define different levels of trauma severity. This has been accomplished using Injury Patient Management Categories (PMCs), a computerized classification that is both clinically specific and linked with different levels of care.[2] Using PMCs, multiple system injuries can be differentiated from single injuries, and specific comorbid conditions and complications are identifiable.[3] Each PMC also has associated with it a Relative Intensity Score (PMC-RIS) that is based on the expected resource requirements for patients assigned to that category. When a patient has multiple PMC assignments (reflecting multiple injuries, comorbidity, or complications), one Relative Intensity Score for the patient is derived based on the increase in resource intensity expected for that particular combination of PMCs.[4]

Because this system operates using data that are routinely collected from virtually all acute care hospitals, specific injuries can be identified for analysis in both trauma center and non-trauma center hospitals. For example, using only discharge abstract data, PMCs ac-

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Supported by the National Center for Health Services Research, Grant Number HS05532, 1986–1989.

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curately identified 97.8% of the injured patients included in the Pennsylvania statewide trauma registry from one Level I trauma center.[5] Thus, PMCs seemed to provide a useful clinical framework within which the major trauma patient and trauma severity could be defined and within which outcomes of trauma care could be assessed.

BACKGROUND

In order to understand the basis of subsequent analyses, it is important to briefly review here the PMC assignment process and the derivation of PMC Relative Intensity Scores. A more comprehensive description of the development and application of PMCs can be found in the references listed.

PMC Assignment Process. The overall PMC Classification System (Release 3.2) consists of 852 Patient Management Categories (126 of which are Injury PMCs) that were developed with extensive physician consultation obtained through the formation of approximately 50 disease-specific panels of four to six physicians each.[4] In addition to Injury PMCs, categories are defined for all patient disorders treated in general, acute care hospitals, including medical/surgical diseases (e.g., diabetes, pneumonia, vascular emboli), specific complications (e.g., septicemia, wound dehiscence, hemorrhage), psychiatric disorders, and diseases related to special populations (e.g., neonates). Since its original development (1978–1985), the PMC Classification System has been reviewed and used by numerous other physicians, nationally and internationally. The Injury PMCs were refined as part of NCHSR Grant No. HS05532.[6]

The Computerized PMC System uses the unique combination of *International Classification of Diseases* (ICD-9-CM) diagnosis and procedure codes listed on a patient's abstracted medical record to assign one or more clinically specific PMCs to each patient record in a given database.* Unlike other classifications that are driven by the principal diagnosis code listed on the patient's abstract (such as DRGs), PMCs use combinations of specific diagnosis and procedure codes (disregarding the sequence or order in which they are listed on the patient's abstract) to accurately define the clinical condition(s). The PMC Classification System permits multiple assignment to different injury/disease modules, thus identifying each clinically significant injury sustained by each patient, as well as specific comorbid conditions and complications.

An example will illustrate the importance of the inter-relatedness of diagnosis codes as well as the importance of identifying specific injuries affecting multiple body systems. Table 1 includes the ICD-9-CM diagnosis codes that were required to describe injuries within two body systems—an ophthalmic injury and a thoracic injury. The Patient Management Category computerized algorithm searches the list of diagnosis codes to determine the two injury areas, each of which are modules in the PMC Software. Within each module, the combination of specific diagnosis codes describing the injury is used to make the PMC assignment.

In the example shown, the patient is assigned three PMCs although five diagnosis codes are present. Within the Ophthalmic Injury Module, rupture of the eye (ICD-9-CM code 871.20) takes precedence over laceration of the eyelid (ICD-9-CM code 870.10) in terms of severity and resource intensity, and the patient is assigned to PMC 2803, Ophthalmic Injury: Laceration/Rupture of Cornea/Sclera. The third, fourth, and fifth diagnosis codes listed on this patient's discharge abstract are all related to multiple thoracic injuries, which are also identified using PMC Classification Software. In this case, the combination of all three codes is used to assign the patient to PMC 3314, Thoracic Injury: Flail Chest, which implies the existence of multiple rib fractures, and PMC 3306, Thoracic Injury: Pneumothorax/Hemothorax without Operation, which further specifies the severity of the thoracic injury.

TABLE 1
Example of PMC assignment process

ICD-9-CM Diagnoses	PMC Assignments
871.20 Rupture of eye	PMC 2803 Ophthalmic Injury: Laceration/Rupture of Cornea/Sclera
870.10 Laceration of eyelid	
807.40 Flail Chest	PMC 3314 Thoracic Injury: Flail Chest
807.00 Fracture of rib(s), closed	PMC 3306 Thoracic Injury: Pneumothorax/Hemothorax without Operation
860.00 Traumatic pneumothorax	

This type of patient, with multiple related codes describing a single injury and with multiple injuries in different body systems, is not atypical. Especially for analysis of trauma care, it is critical that a patient classification: (1) incorporate severity distinctions by accounting for the clinical inter-relatedness of diagnosis codes; and (2) permit the identification of specific injuries affecting multiple body systems, as is done by PMCs.

PMC Relative Intensity Score. During the original PMC development, panels of physicians not only identified unique patient types (PMCs) within each disease and injury area, but also specified components of care for each category, including diagnostic tests, treatment, length of stay, and special care unit days. These components of care, representing an effective management strategy for a typical patient in each category, are referred to as a Patient Management Path. An example of the form that this takes is shown in Figure 1.

The PMCs that are shown in this example are PMC 0508, Burn: Smoke Inhalation with Inhalation Injury, and PMC 0509, Burn: Smoke Inhalation without Inhalation Injury. These two categories, along with nine other burn injury patient types, constitute the Burn Injury PMCs (Module 05). A patient is assigned one of these categories using a combination of diagnosis codes (in any sequence) taken from patient discharge abstract data that are collected by virtually all acute care general hospitals.

The services specified on each Patient Management Path represent effective and efficient resource use for a typical patient in each category; they do not represent a standard of care. The components of care were the basis for the identification of expected hospital costs for each patient type, which were then used to derive a cost-based relative value scale for PMCs, reflecting the relative intensity of expected resource requirements for each patient type.

Specifically, patient-related hospital costs (derived through detailed cost finding) were identified for each component of care and then accumulated for each Patient Management Category to determine the expected cost of managing that patient type. These patient-related costs were then used to derive a cost-based relative weight for each PMC. In the burn care example shown in Figure 1, both smoke inhalation patient types require the availability of an emergency room and are typically managed with oxygen and laboratory and radiology studies. The category smoke inhalation with inhalation injury requires additional resources, including drug therapy, respira-

* The variables used by the PMC Classification Software include up to 20 diagnosis codes and 20 procedures, along with age and gender of the patients.

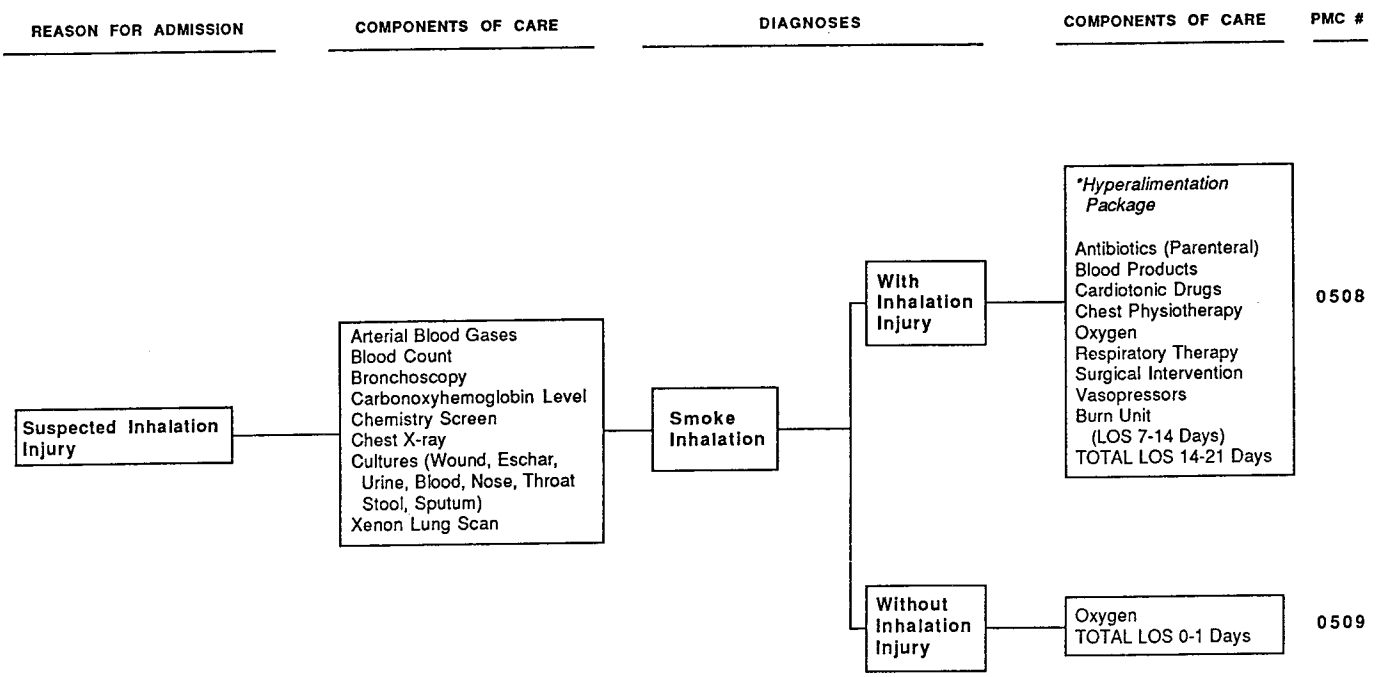

FIG. 1. Sample patient management path—Burn: Smoke Inhalation.

tory therapy, possible surgical intervention, and the availability of a special care unit for 7 to 14 days. The total length of stay expected for this inhalation injury patient is 14 to 21 days in contrast to only 0 to 1 day of acute care for the smoke inhalation patient without inhalation injury. Physicians have, in fact, designated the latter PMC as a potential ambulatory patient type.

These resource requirements for each patient type are translated into cost-based relative weights and are referred to as PMC Relative Intensity Scores (PMC-RIS). The significant difference in resources required in the management of these two burn injuries is reflected in the category weights shown in Table 2. That is, managing a patient with an inhalation injury is more than eight times as costly as managing a smoke inhalation patient without inhalation injury.

In this way, PMCs define clinically specific case types and can be used to differentiate patients with different resource needs (as opposed to differentiating patients based on resource use). Since severity distinctions were made by physicians in defining categories, severity is implicitly measured in the PMC Classification System. Severity is also measured indirectly by the relative intensity scores since, in most instances, severity is directly related to intensity and costliness. Other severity scales are based on subjective clinical judgment of differences in morbidity within diseases and generally result in ordinal scales (where 4 is greater than 2, but not necessarily twice as great) rather than interval scales (where 4 is twice as great as 2). By contrast, PMC Relative Intensity Scores are based on the relative costs of treating patients of different severity and with different resource needs, and thus they can be used as an interval scale across diseases to adjust and predict costs, lengths of stay, and various measures of morbidity and mortality.

A patient with a relative score of 1.0 is similar to the average hospitalized patient in the standard population. Interpretations of intensity scores are always relative to that average patient. Thus a patient with a relative intensity score of 1.2 is expected to be 20% more costly than the average patient in the standard population, requiring more services because of the increased complexity of his or her condition(s). Similarly, a relative intensity score of 0.8 is 20% below the average of the standard population.

The example shown above indicates the method used to assign a PMC-RIS to a patient with a single PMC assignment. Recall, however, that the PMC computerized algorithm permits a single patient to receive multiple PMC assignments to reflect multiple injuries, specific comorbid conditions, and complications. When this occurs, one relative intensity score for the patient is derived by merging the cost-based weights associated with the overlapping services (counting them only once) and combining them with the cost-based weights of the unique services associated with each condition. (As part of the PMC Classification System, software exists to carry out this scoring process automatically.) This methodology[†] yields one PMC-RIS for the patient that is not additive of the individual PMC scores, but instead represents an adjustment upward to reflect the increased resource use expected by patients with multiple injuries and complications.

Table 3 shows the upward adjustment for the patient described previously (Table 1) who had an ophthalmic injury and multiple thoracic injuries. If this patient had only the eye injury, the PMC-RIS would have been 1.36, reflecting the surgical management required for the eye injury alone. A patient with only a flail chest would be assigned a PMC-RIS of 2.08, reflecting more resource-intense management, while the pneumothorax alone requires less intense management as indicated by its

TABLE 2
PMC Relative Intensity Scores for two patient types

Patient Management Category	PMC-Relative Intensity Score
PMC 0508: Smoke Inhalation With Inhalation Injury	5.85
PMC 0509: Smoke Inhalation Without Inhalation Injury	0.69

[†] A more detailed description of this methodology can be found in Young, W., et al.: "Measuring the Cost Care Using Patient Management Categories, Volume II: Relative Cost Weights," HCFA Final Report, Grant No. 18-P-97063/3, 1978–1985.

TABLE 3
PMC-RIS adjustment for multiple injuries

	PMC Assignments	PMC-RIS
PMC 2803	Ophthalmic Injury: Laceration/Rupture of Cornea/Sclera	1.36
PMC 3314	Thoracic Injury: Flail Chest	2.08
PMC 3306	Thoracic Injury: Pneumothorax/Hemothorax without Operation	1.13
	Multiple Injury Combination	3.15

PMC-RIS of 1.13. A patient with this particular combination of injuries, however, is assigned a PMC-RIS of 3.15, reflecting the increased resource use that is expected for this particular combination of injuries.

In general, the PMC Relative Intensity Score (PMC-RIS) is based on the unique combination of specific injuries and comorbidities of the patient. Thus this total intensity score for each patient reflects the intensity of management required for the injury or injuries sustained, plus complications and concomitant conditions (if any) being managed in the same hospitalization. A PMC Relative Injury Intensity Score (PMC-RIIS) is also defined for each injured patient, which reflects the resource intensity for only injuries sustained. The PMC-RIS and PMC-RIIS will be equal if the patient has acute injuries only, with no complications or concomitant conditions.

This classification and scoring process has been applied to all acute-care, hospitalized patients in various regional and statewide databases.[‡] Approximately 99% of patients receive scores ranging from 0.03 (reflecting ambulatory management) to 6.0 (reflecting a more severe patient type, requiring more intense and costly management); 95% of patients generally have a PMC-RIS below 4.0.

In most databases, injured patients are more complex than the average patients in the overall hospitalized population. Approximately 99% of all injured patients receive PMC Relative Intensity Scores ranging from 0.06 to 7.4 and PMC Relative Injury Intensity Scores ranging from 0.06 to 6.6. Since the amount of the adjustment associated with multiple injuries, comorbidity, and complications depends on the unique combination of conditions that exist for a patient, there is no upper limit on either weighting scale. In practice, the maximum PMC-RIS value for an injured patient in 1989 databases has been 14.6.

PMC TERTIARY PATIENT CRITERIA

One of the major objectives of this research has been to define patient types that require tertiary levels of care and to use these operationalized tertiary patient criteria to create an analytical model for the assessment of trauma regionalization and effectiveness. This was accomplished through an iterative process of combining clinical judgment with data review. The clinical description of each PMC, along with data for patients assigned to that PMC, were reviewed by three physician co-investigators who are trauma surgeons at three Level I trauma centers in the state of Pennsylvania. (Only one of these three trauma surgeons participated in the physician panels that were part of the original development of the PMCs.) The three physicians, working with health services and nurse investigators, were able to reach consensus about the operational criteria to be used in the initial phase of this analysis to identify tertiary patients.

The first step in this process was for physicians to assign each of the 126 Injury PMCs to one of the following three levels of severity: (1) minor injuries, (2) significant injuries, and (3) tertiary injuries. This was possible primarily because Injury PMCs are clinically specific categories that were defined by physicians, and thus are consistent with their clinical training and experience. The designation made for each PMC is shown in *Appendix 1.*

Minor injuries were perhaps the most readily identified because, although patients with a single minor injury are in fact injured in the broadest sense of that term, they do not require the specialized services of trauma centers. In fact, in many cases, minor injuries may not even require admission to an acute care facility. Under reasonable circumstances, there should be no risk of death associated with these injuries and, in many instances, trauma surgeons prefer that these types of patients be excluded from trauma care analyses. Examples of injuries designated as minor are Uncomplicated Contusion/Superficial Wound (PMC 4720), Uncomplicated Sprain or Strain (PMC 4721), and Closed Fracture or Dislocation of the Hand or Foot (PMCs 2925, 2926, 3017, 3018).

Next, the physician co-investigators assigned the tertiary injury severity level designation to the most severe and complex single injuries as defined by PMCs. Tertiary level PMCs were identified in all 11 injury modules and are listed in *Appendix 2.* A patient with any one of these injuries, with or without other injuries, is defined as a major trauma patient. Examples of injuries that were designated as tertiary are Head Injuries with Hematoma/Edema (PMCs 3505–3508), Spine Fractures with Cord Injuries (PMCs 3403–3405), Penetrating Cardiac Injury (PMC 3308), and Flail Chest (PMC 3314). It should be noted that many of these tertiary level PMCs such as Open Pelvic Ring Fracture (PMC 4803) cannot be identified without special programming logic which is provided by PMCs, permitting the aggregation of combinations of ICD-9-CM diagnosis codes to define specific clinical conditions.

Other PMCs were designated tertiary even though only a particular subset of patients in that category require specialized trauma center services. For example, Myocardial Contusion (PMC 3304) should probably be designated as tertiary only if it is associated with certain complications such as congestive heart failure, dysrhythmia, or valve disruption. An initial data review indicated that there were approximately 30 patients with only PMC 3304, Myocardial Contusion, but three times as many patients with myocardial contusion along with other significant injuries. Because the complications listed above will require additional refinement of the tertiary programming logic, it was decided to include all myocardial contusions as tertiary until such refinements could be made.

In addition to the single injuries that were identified as the most severe and complex, a definition of the major trauma patient should also include criteria for identifying combinations of injuries that require the comprehensive and specialized service availability and expertise of a trauma center. To accomplish this task, narrative descriptions of specific combinations of injuries and complicating conditions were sought from various authoritative sources, including published literature, physician co-investigators, and other trauma surgeons and EMS consultants. The resultant list of injury combinations was operationalized using combinations of PMCs along with computerized selection criteria.

These additional PMC tertiary patient criteria are also doc-

[‡] The PMC Classification System has been applied to the following statewide databases: Florida, Iowa, Maine, Maryland, New York, Pennsylvania, and Washington. PMCs have also been the basis of demonstration projects in Spain, Australia, the United Kingdom, and West Germany.

umented in *Appendix 2.* Certain injuries (e.g., extremity vascular injuries) are not defined as tertiary when they occur alone but, when they occur with any other significant injury, they are designated as major trauma that typically requires more specialized services. Other injuries must occur in specific combinations to be considered tertiary. For example, Closed Pelvic Ring Fracture without open reduction and internal fixation (ORIF) is only defined as tertiary when it occurs with specific abdominal or spine injuries.

When these clinically specific PMC tertiary patient criteria were computerized, there were still patients with certain multiple injuries that, in the judgment of clinicians, should be defined as major trauma patients. Although these tertiary PMC selection rules could be expanded to cover more specific combinations of injuries, given the scope of this project, a decision was made to identify additional tertiary patient criteria using conservative empirical thresholds. Specifically, if a patient has a combination of any three significant level injury PMCs or any two significant injury PMCs with a combined PMC-RIIS ≥ 4.0, the patient is defined as tertiary (Injury PMCs that are not otherwise defined as tertiary or minor are referred to as significant) (See *Appendix 1*).

The last tertiary patient criterion (patients who are less than 55 years of age with certain femur/pelvic injuries) was added to the list by other surgeons who reviewed these criteria before they were implemented in a state-supported research project to assess the extent of regionalization. This criterion was added to try to identify major femur/pelvic injuries that were more likely to be sustained as a result of high-impact accidents.

Subsequent analyses of tertiary patients presented in this report are based on these criteria. It is clear, however, that these tertiary criteria require further refinement. Certain patient types (e.g., myocardial contusion, diffuse axonal injury) and certain combinations of severe injuries (e.g., multiple abdominal organ injuries) may need to be identified more specifically. The way that these categories were defined and designated was sometimes limited by data and/or funding constraints. Because the tertiary patient criteria that have been identified here are computerized, however, they can be readily modified with more empirical results and more extensive review by other physicians. They are presented here now so that such review can take place.

DATA AND METHODS

These tertiary patient criteria can be implemented using hospital discharge abstract data routinely collected in all acute care general hospitals, both trauma centers and non-trauma centers. In this study, the injury criteria were applied to two databases—registry data and abstract data—so that we could assess the differentiation of injury patient types that is achieved by using these definitions. One database is a trauma registry which includes 2 years of detailed data from six trauma centers located throughout the state of Pennsylvania (N = 10,475 injured patients). The other is an EMS episode database comprised of discharge abstract data from four trauma centers and 39 non-trauma centers (N = 27,831 injured patients) linked with regional prehospital ambulance data and with more detailed registry data from trauma centers in the region to identify transfer patterns.

The assignment of PMC Relative Intensity Scores is also computerized, and thus a PMC-RIS and a PMC-RIIS were assigned to each patient in both databases. It should be emphasized that the only data required to assign PMCs, severity levels, and PMC Relative Intensity Scores to each patient are ICD-9-CM diagnosis and procedure codes, age, gender, and discharge status of the patient (i.e., dead/alive).

No attempt has been made to generalize the patterns of care found in these data to other populations. Instead, these data are presented to assess the tertiary criteria developed and to demonstrate that such regional analyses can be undertaken in other areas of the country where the types of injuries encountered may be quite different. PMCs provide an analytic tool to identify and assess these differences.

RESULTS

Defining Trauma Severity. Using the trauma registry database from six trauma centers in Pennsylvania, the PMC-based definition of the major trauma patient was compared with other definitions that are typically available only in such detailed trauma registries. Tables 4 and 5 show the distribution of minor, significant, and tertiary patients (as defined by PMCs)

TABLE 4
Classification by PMC injury severity level and maximum AIS score

AIS	Minor N = 1,462 (%)	Significant N = 4,464 (%)	Tertiary N = 4,549 (%)
≤2	92.0	61.0	13.8
3	6.6	36.9	45.3
≥4	1.4	2.1	40.9
	100.0	100.0	100.0

TABLE 5
Classification by PMC injury severity level and ISS ranges

ISS Range	Minor N = 1,462 (%)	Significant N = 4,464 (%)	Tertiary N = 4,547 (%)
0–8	90.6	53.2	12.7
9–15	7.6	41.3	36.4
16–24	0.8	4.7	21.9
25–39	1.0	0.8	21.8
40–75	0.0	0.0	7.2
	100.0	100.0	100.0

TABLE 6
Frequency and intensity of trauma by injury severity level

Severity Level	Frequency	Death Rate (%)	Average Injury Intensity Score (PMC-RIIS)
Tertiary injuries	2,967	10.6	3.4
Significant injuries	15,787	1.2	1.3
Minor injuries	5,808	0.7	0.5

TABLE 7
Percentage distribution by injury type

Injury Type	Significant Injury (%)	Tertiary Injury (%)
Head	18.7	36.7
Femur/Pelvic	23.3	30.0
Thoracic	9.9	16.8
Abdominal	2.2	13.9
Maxillofacial	3.2	13.0
Upper Extremity	25.5	12.4
Spine	0.6	10.7
Lower Extremity	23.7	10.0

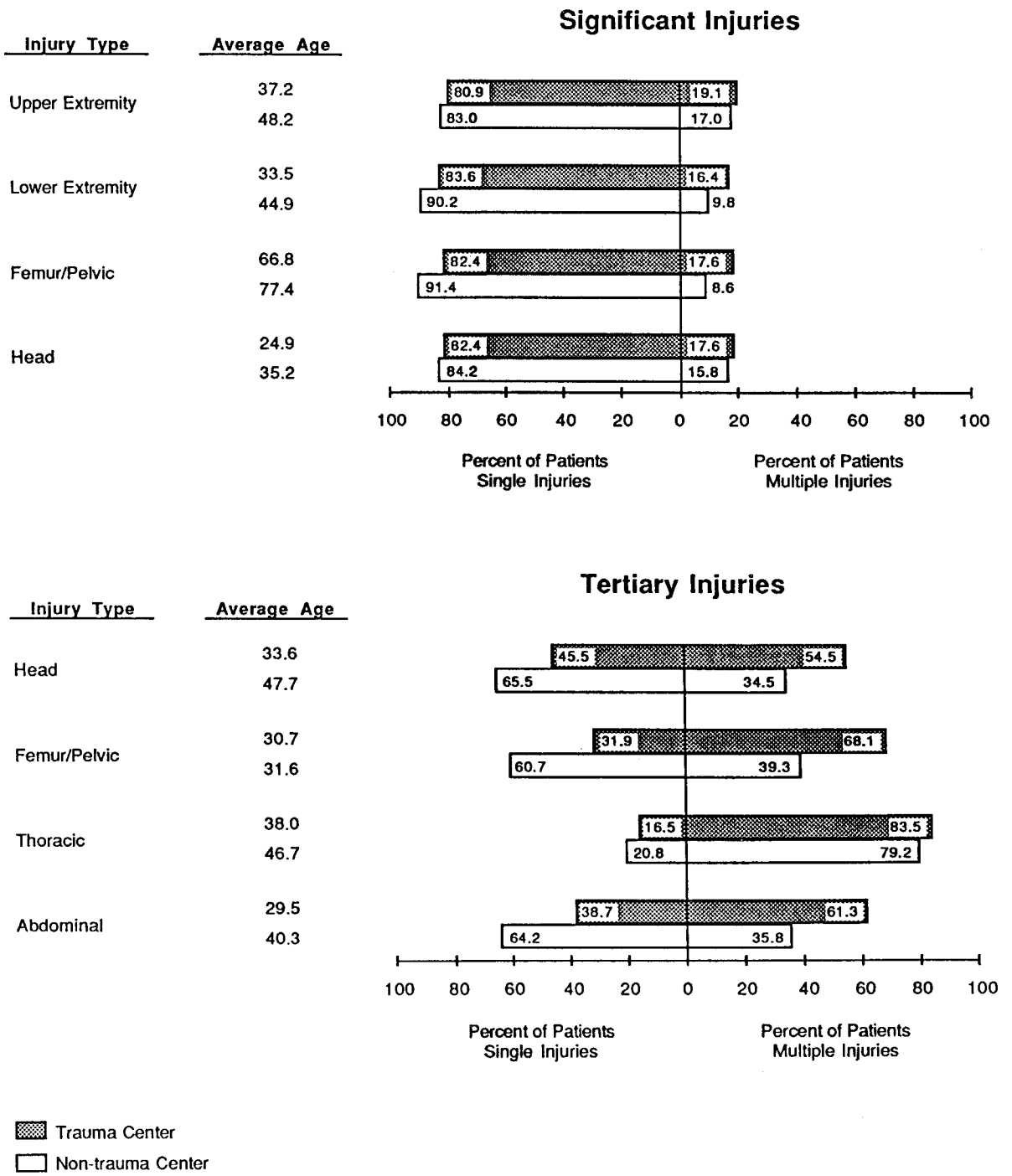

FIG. 2. Percentage distribution of single vs. multiple injuries by injury type.

by the patient's maximum Abbreviated Injury Score (AIS) and the Injury Severity Score (ISS), respectively. Although scoring systems such as AIS and ISS do not permit the specific classification of injuries as PMCs do, they are frequently used to define gross patient severity levels.

For instance, major trauma patients are often identified as patients having a maximum Abbreviated Injury Scale (AIS) score of 4 or greater. In the registry database shown in Table 4, nearly all of the patients with AIS $\geq$ 4 are also defined as tertiary by PMCs. By contrast, only 40.9% of the major trauma patients defined by PMCs had a maximum AIS of 4 or greater. It is clear, however, that using AIS to define major trauma patients underestimates tertiary patients because it does not specifically account for multiple injuries that together are more severe and require more intense management. Illustrative of this point is the fact that, of the tertiary patients with a maximum AIS $\leq$ 3, approximately half had multiple significant injuries that are defined specifically by PMCs.

To address the problem of identifying multiply injured

TABLE 8
Mechanism of injury by PMC Injury Severity Level: N = 1,852

Cause of Injury	Significant Trauma				Tertiary Trauma			
	Percent of Cases	Average Age (yrs)	Average LOS	PMC-RIIS*	Percent of Cases	Average Age (yrs)	Average LOS	PMC-RIIS*
Motor vehicle accident	26.2	35.5	8.1	1.4	42.7	33.7	17.5	4.2
Motorcycle	3.6	28.9	9.9	1.7	7.4	26.4	18.3	4.4
Pedestrian	5.6	31.4	11.1	1.5	6.7	30.2	21.6	4.0
Gunshot	1.7	27.8	9.5	1.9	5.1	32.2	13.8	3.7
Stabbing	7.3	31.3	6.2	1.6	6.9	27.9	8.3	4.0
Falls	37.2	49.1	10.0	1.5	14.8	41.8	13.0	3.3
Other	18.5	27.7	5.9	1.4	16.5	26.3	15.4	3.8

* Average PMC Relative Injury Intensity Score.

TABLE 9
Treatment setting (trauma center versus non-trauma center) for single-injury tertiary patients by place of service

Single Injury Tertiary Criteria (See Appendix 1)	Percentage of Patients		Total Number of Patients
	Trauma Center	Non-trauma Center	
Acetabular or pelvic ring fractures	85	15	39
Abdominal: Major organ or vascular injury	61	39	54
Spine injuries: Cord injuries w or w/o fracture	59	41	223
Head injury with moderate/prolonged LOC or depressed skull fracture	55	45	142
Thoracic injuries	52	48	91
Head injury: Hematoma with no/brief LOC with an operation	48	52	118
Abdominal: Minor organ injury with exploration or operation	46	54	143
Upper/lower extremity injuries	46	54	70
Head injury: Hematoma with no/brief LOC without operation	41	59	312
Multiple facial fractures	33	67	142
Femur fractures ≤ age 55 years	28	72	369

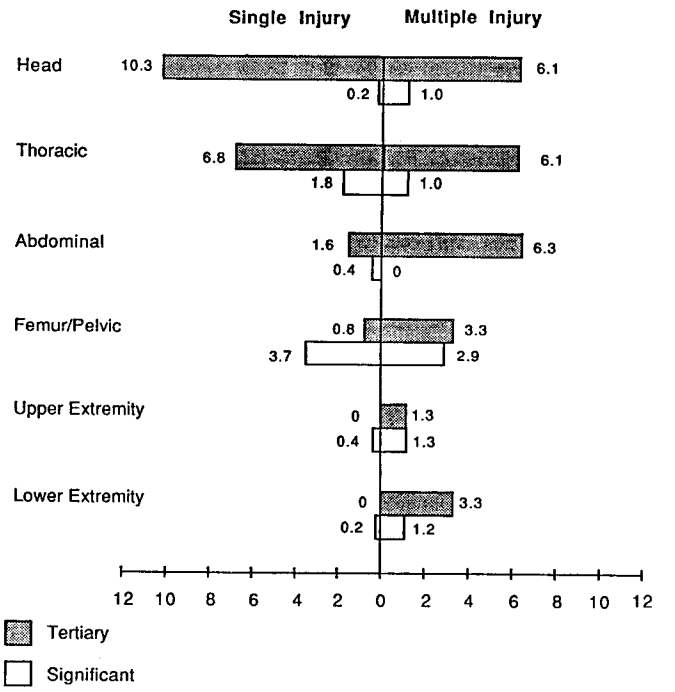

FIG. 3. Percentage of in-hospital deaths by injury type: Significant vs. tertiary.

TABLE 10
Unadjusted in-hospital mortality rates for significant and tertiary patients

	Significant		Tertiary	
	Number	Percent	Number	Percent
Trauma center	19	0.66	157	10.18
Non-trauma center	189	1.49	72	5.30

TABLE 11
In-hospital mortality rates: Blunt and penetrating injuries

Type of Injury	Significant Injury N = 1,301		Tertiary Injury N = 1,099	
	Percentage of Cases	Percentage Dead	Percentage of Cases	Percentage Dead
Blunt	88.6	1.1	86.1	10.4
Penetrating	11.2	2.1	13.8	11.2
Unknown	0.2	0.0	0.1	100.0
Overall	100.0	1.2	100.0	10.6

patients, including those who require tertiary care, an ISS ≥ 16 has frequently been used in registry databases. Table 5 shows that most of the patients with an ISS ≥ 16 are tertiary level patients as defined by PMCs, but there also appear to be many tertiary patients that have Injury Severity Scores lower than 16. These cases can be identified more specifically by PMCs so that physicians can assess each type of case and determine whether it should be considered tertiary, requiring specialized services and staff.

For example, nearly all of the tertiary patients with an ISS between 9 and 15 have either a femur fracture, acetabular fracture, or pelvic ring fracture. A patient with one of these fractures is assigned an AIS of 3, and thus an ISS of 9. In this particular instance, physician investigators on this project chose only to include acetabular and open and closed pelvic ring fractures requiring ORIF as tertiary. In their opinion all other femur fractures should be defined as significant (not tertiary)

unless other injuries are also present. Recall that femur fracture patients with age ≤ 55 years were added to the tertiary criteria as part of a Pennsylvania state-supported project. Both of these alternative sets of tertiary patient criteria (defined by physician investigators and defined for the Pennsylvania state project) have been computerized using PMCs.

It has been shown that the PMC tertiary patient criteria are consistent with other less available measures of severity and are more flexible to use because specific injury types can be identified. In addition, unlike AIS and ISS, the PMC tertiary criteria can be applied to large databases consisting of non-trauma center hospitals as well as trauma centers. This is a major advance for the analysis of injury data to assess regionalization and effectiveness.

The frequency and intensity of trauma patients by injury severity level in one EMS region are shown in Table 6. As shown, the average PMC Injury Intensity Score (PMC-RIIS)[§] for tertiary patients is 2.6 times as high as the average PMC Relative Injury Intensity Score for patients with significant injuries (3.4 versus 1.3). Similarly, the average PMC Injury Intensity Score for patients with significant injuries is 2.6 times higher than the average PMC Injury Intensity Score for patients with minor injuries (1.3 versus 0.5). The differences in the injury intensity weights reflect the clinical and severity distinctions made by the PMCs, which is also shown in Table 6 by the differences in in-hospital mortality rates for these groups of patients. Patients with tertiary injuries have an in-hospital death rate of 10.6%, which is substantially higher than the 1.2% rate of in-hospital deaths for patients with significant injuries. The deaths associated with minor injuries were reviewed and, in nearly all cases, death was the result of other morbid conditions or complications rather than the minor injury.

Describing Specific Injury Types. Since PMCs, unlike various injury scoring systems, can be used to characterize injury types more specifically, all significant and tertiary level injuries in the larger EMS regional database were assigned to the appropriate injury site(s) as defined by the regions of the body listed in Table 7. Patients with multiple injuries contributed to the population only once, but their injuries were counted in each site of injury in order to assess injury-specific incidence rates. As shown in Table 7, upper and lower extremity and femur/pelvic areas are the predominant injury sites among significantly injured patients. Each of these three types of injuries affects approximately one fourth of all significantly injured patients. By contrast, the types of injuries that most frequently occur among patients requiring tertiary care in this geographic region are head injuries (36.7%) and femur/pelvic fractures (30.0%). Abdominal (13.9%) and thoracic injuries (16.8%) are also frequent among tertiary patients.

As noted, both tertiary and significantly injured patients can have either single or multiple injuries. For example, a patient who has a fractured humerus (upper extremity) and a superficial scalp laceration (head) has more than one injury, but, in the judgment of the project's clinical consultants, this patient does not require tertiary care. Using PMCs and the PMC tertiary patient criteria, it is possible to differentiate patients with multiple injuries who typically require tertiary care from those with less severe injury combinations who do not require tertiary care.

As expected, when these criteria are applied to a regional database, multiple body system injuries are more common among tertiary patients (40.1%) than among significant injury patients (9.3%). Figure 2 shows the relative proportions of single versus multiple body system injuries in each of the high-frequency significant and tertiary injury types. In all injury types, trauma centers have a statistically significant higher percentage of multiple injury patients than non-trauma centers. This difference is particularly pronounced among tertiary patients. In both trauma centers and non-trauma centers, significant injuries are primarily single injuries, while tertiary injuries are predominantly single in non-trauma centers and multiple in trauma centers. Tertiary thoracic injuries are an exception to this and occur with other body system injuries nearly 80% of the time regardless of where they are treated, trauma centers or non-trauma centers.

Figure 2 also shows the average age of significantly injured and tertiary patients for each of the high-frequency injury types. For each injury type and regardless of single- or multiple-injury status, the average age of patients treated in trauma centers is lower than that of patients in non-trauma centers.

To assess mechanism of injury by injury severity level, the merged registry/discharge abstract database was used. Table 8 shows the frequency of mechanism of injury reported in the registry database. Among patients with significant injuries, the most frequently reported cause of injury was a fall (37.2%), the longest length of stay was associated with pedestrian accidents (11.1 days), and the most complex injuries were associated with gunshot wounds (1.9 PMC Injury Intensity Score). Among patients with tertiary injuries, motor vehicle accidents were the highest in volume (42.7%), the longest length of stay was again associated with pedestrian accidents (21.6 days), and the most complex injuries resulted from motorcycle accidents (4.4 PMC Injury Intensity Score).

Note that the average length of stay for tertiary patients in certain categories (e.g., motor vehicle, motorcycle, and pedestrian) is nearly twice as high as it is for significant injuries in those same areas. In three other categories (i.e., gunshot, stabbing, and falls), tertiary patients stay 30% to 45% longer than those patients

[§] The PMC-RIIS is derived in the same way as the PMC Relative Intensity Score, except that only injuries (not complications or comorbid conditions) are included in the calculation of the score.

identified as significant. This capability of differentiating length of stay and Injury Intensity Scores by PMC Injury Severity Level (tertiary versus significant) is a substantial improvement for explaining variation in lengths of stay for various types of injury mechanisms and across types of institutions. Such differentiation is, in fact, possible because of the availability of PMC tertiary patient criteria.

One reason for establishing tertiary patient criteria that can be applied retrospectively is to determine whether the patients who require the specialized services of a trauma center actually receive that level of care. Using these criteria in one regional database, however, approximately half of the patients identified as tertiary were actually treated in non-trauma centers. Does this mean that the tertiary patient criteria are too broad, or that the tertiary patients were not triaged properly to the appropriate facility? To answer this question, an analysis of the tertiary patients treated at non-trauma centers was conducted. Patients were characterized by the number of injuries (single versus multiple) and, for the single tertiary patients, by the specific injury that was responsible for their designation as tertiary.

Overall, approximately one third (31.7%) of the tertiary patients treated at non-trauma centers had multiple significant injuries.[¶] The specific combinations of injuries recorded on the abstracts of these patients were reviewed by a nurse investigator in order to make a subjective assessment of whether these cases should be defined as tertiary. No medical record review of these patients' records was possible given the scope of this study and the large number of non-trauma center hospitals included (N = 39). The result was the determination that these multiply injured patients were in fact patients who should have been triaged to trauma centers for the specialized services and teams of personnel available there. The multiply injured patients, defined as tertiary but treated at non-trauma centers were therefore reasonably defined as major trauma patients.

The remaining tertiary patients treated at non-trauma centers had single tertiary injuries (68.3%). All of these patients had a single tertiary PMC assignment with no other injuries recorded. More than half of these single-injury tertiary patients treated at non-trauma centers were defined as tertiary based on two criteria—Head Injury: Hematoma with No/Brief LOC and Femur Fractures age ≤ 55 years. The question of whether or not these patient types are tertiary and require the specialized facilities and staff of a trauma center is best answered through a review of medical records of patients treated in multiple settings and a determination of the extent of overtriage versus undertriage that is acceptable.

For each tertiary criteria that determined classification status,[‖] Table 9 shows the way that single injury tertiary patients were distributed between trauma centers and non-trauma centers. All of the single injury classification criteria shown here (and in more detail in *Appendix 1*) were defined to identify patients who should be managed in trauma centers. In some instances (e.g., Acetabular or Pelvic Ring Fracture, and Major Abdominal Organ Injuries), it appears that the great majority of these major trauma patients are already treated in the four trauma centers in this EMS region. Other criteria represent the identification of patients who have a high probability of extended morbidity and mortality, especially if their injuries are missed or are underidentified. It is for this reason that these criteria were determined a priori, using clinical judgment, to represent tertiary patients. However, if outcomes are similar across hospitals, it may be desirable to omit the last two criteria listed (i.e., multiple facial fractures and femur fractures in patients age ≤ 55 years) from the PMC tertiary patient criteria. These results, together with results obtained using the trauma registry database, AIS, and ISS, indicate that certain modifications to the PMC tertiary patient criteria may be desirable.

Mortality in Major Trauma Patients. Many of the indicators that are readily available to assess hospital effectiveness are somewhat inadequate, especially as isolated measures. Nevertheless, there is a great deal of interest in having baseline data for some of these indicators, such as in-hospital mortality rates, probabilities of survival, and risk ratios. It must be emphasized that these analyses are based on the number of deaths for every 100 patients in the hospitalized population as opposed to the typical epidemiologic death rate per 1,000 persons in the population. The in-hospital mortality reported here does not include deaths that occur before arrival at the hospital or deaths that occur after the patient has been discharged from the hospital, even though these deaths may have been a result of, or associated with, the injury.

As shown in Table 10, the raw death rate of patients with significant injuries in trauma centers is 0.66%; the death rate in non-trauma centers is 1.49%, more than double the rate in trauma centers. Table 10 also shows that the reverse relationship is true for tertiary patients. That is, the raw death rate for tertiary patients in trauma centers is 10.18%, almost double that of non-trauma centers (5.3%). Whether or not these deaths were preventable can only be determined after medical record review.

Nevertheless, there are a few patterns that are worth noting. Approximately 91% of all significant injury deaths occur in non-trauma centers, and two thirds of these deaths are associated with femur fractures in elderly patients. In addition, although 69% of all tertiary

[¶] These patients not only met the PMC tertiary patient criteria, but they also had two or more injuries defined as significant or tertiary severity level.

[‖] Patients defined as tertiary based on the empirical criteria are not included because they represent such a small percentage of tertiary patients.