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Summary

Problem

Modeling and simulation applications require accurate estimations of the number and type of injuries and illnesses. These estimates, called patient streams, include projections of the patient condition (PC) code frequencies needed for estimating medical resources for various types of military operations. They are the diagnostic nomenclature that modeling and simulation applications use. Currently, no quantitative process has been developed to estimate these patient streams.

Objective

The objective of this research was to develop a methodology that links hospitalization data to the PC code nomenclature. In addition, patient streams resulting from specific causative agents would be estimated by associating the traumas and anatomical locations that result from a specific weapon. Finally, a tool using this quantitative approach would be developed that allows the user to select one of these methods to easily calculate the patient distributions.

Approach

Two approaches to estimate PC code patient streams were addressed. The first approach linked trauma and anatomical location percentages to PC codes for selected operations. Diagnostic data obtained from Operation Iraqi Freedom (OIF) were grouped and coded to illustrate the estimation of a patient stream in terms of PC codes using the first approach. In the second approach, using OIF and Vietnam data, patient streams were estimated from the traumas resulting from the causative agents expected to be used by enemy forces.

Results

The Patient Condition Occurrence Frequency (PCOF) tool was developed to allow the user to estimate various patient distributions based on operation type or causative agent.

Discussion

This study provides medical planners the ability to easily generate patient streams using a quantitative and a mathematical approach. These approaches provide patient streams from the different phases of OIF, and illustrate the potential application of the tool for generating patient streams for future operations in support of the global war on terror.

Introduction

Forecasting medical resource requirements during combat operations is contingent upon obtaining reliable estimates of the medical workload and threat to the Health Service Support (HSS) system. These estimates include (1) overall wounded in action (WIA) and disease and non-battle injury (DNBI) incidence rates expected to be incurred by the deployed forces, (2) distribution of injuries and illnesses of which the patient streams are likely to be composed, (3) causative agents likely to be used by the enemy, and (4) geographical region of the theater of operation. Injury and disease rates, causative agent, and geographical location have a major impact on the distribution and number of expected casualties.

Joint Publication 4-02[1] specifically requires that estimates be calculated for the total number of casualties and distribution of casualties, including mass casualty situations. This information is important for medical planners to optimally determine the amount and composition of the medical staff, equipment, and supplies needed for an operation. In addition, determining the likely distribution of injuries and illnesses requiring treatment at the various medical facilities is required by the Joint Task Force Surgeon to propose the best course of action to provide treatment for the casualties.

One HSS medical planning tool currently used is the Medical Analysis Tool (MAT).[2] MAT was developed to provide theaterwide medical analytic and clinical decision support during planning, programming, and deployment. MAT provides medical planners the level and scope of medical support needed for a joint operation, and the capability of evaluating courses of action for probable scenarios.

In addition to MAT, the Estimating Supplies Program (ESP)[3] and the Tactical Medical Logistics planning tool (TML+)[4] require patient stream input in the form of patient condition (PC) codes, a system of more than 400 possible medical conditions to which treatment resources are tied. These tools estimate and configure the Authorized Medical Allowance Lists, determine the required number of medical specialists, provide overall medical system analysis, and assist in risk assessment and capability-based planning.

PC codes are the diagnostic nomenclature for the injuries and illnesses that MAT, ESP, and TML+ use to generate patient streams. PC codes were developed under the Deployable Medical Systems (DEPMEDS) project, which was initiated to provide a standardized deployable hospital system for the military services. DEPMEDS consisted of deployable medical assets in the form of modular assemblages of standardized equipment and supplies.[5] The Time-Task-Treater database includes information about the providers, tasks, and supplies required for the individual PC codes. Approximately 400 PC codes are used for injuries and illnesses resulting from conventional weaponry, and from nuclear, biological, and chemical warfare.

This paper describes a methodology that uses *International Classification of Diseases,* 9th Revision (ICD-9) diagnostic data to estimate the composition of the projected patient streams in terms of specific PC codes. Two approaches to estimate PC code patient streams are addressed. The first approach associates trauma and anatomical location percentages based on selected operations. Using the first approach, diagnostic data obtained from Operation Iraqi Freedom Phase I (OIF-1) are grouped and coded to illustrate the estimation of a patient stream in terms of PC codes. In the second approach, patient streams are estimated based on traumas resulting from causative agents the enemy can be expected to use. Estimating the traumas that result from expected causative agents provides methods to derive patient streams for major contingency operations (MCO) and for stability and support operations (SASO). MCO and SASO are required scenarios used for planning and budgeting by the Joint Chiefs of Staff. Lastly, the Patient Condition Occurrence Frequency (PCOF) tool is presented that automates this methodology, making it possible to create a variety of patient streams using the aforementioned approaches as well as user-defined scenarios.

Generating a Patient Stream Using Trauma and Anatomical Location Relationships

Methods

Empirical hospitalization data were gleaned from Vietnam, Mogadishu, OIF-1, and OIF-2 operations to generate the needed trauma categories and anatomical location percentages to estimate the PC streams.[6–9] Approximately 10% of the data that did not fall into the PC code categories were excluded and the percentages normalized to 100%. Table 1 shows the normalized results. For this discussion, we focused on battle injuries sustained during hostile engagement with a military adversary.

Vietnam

The Vietnam data were extracted from an inpatient medical database maintained by the Naval Health Research Center.[6] A total of 51,976 active-duty Marine Corps personnel WIA hospitalizations from 1964 to 1972 were used to estimate the patient stream. The WIA casualties were grouped by trauma categories and anatomical locations, the needed data arrangement to generate PC streams.

Mogadishu

The Mogadishu data were extracted from a study of the differences in injury patterns of soldiers equipped with modern body armor compared with Vietnam War-era soldiers.[7] A total of 58 US Army Ranger patients were classified as WIA and sustained 91 injuries. In addition to the aforementioned study, another study provided the trauma categories and the causative agents that were used. Both data sets were used to estimate the PC stream for Mogadishu.[10]

OIF-1

OIF-1 data were obtained from the Transportation Command Regulating and Command and Control Evacuation System (TRAC2ES) database for March–August 2003. TRAC2ES provides transportation planners documentation on patient regulation/movement in the theater of operations, and is currently being used in OIF. The TRAC2ES database provides information on casualty type, ICD-9 codes, time of arrival, time of departure, incident report of the injury or illness, receiving and departing medical treatment facilities, as well as other variables that are outside the scope of this paper. A total of 859 OIF casualties (266 Marines and 593 Army soldiers) were identified for March–August 2003.

OIF-2

The data from the SASO phase of OIF, often referred to as OIF-2, were extracted from the Navy–Marine Corps Combat Trauma Registry (CTR) from March to December 2004 to estimate these patient streams. The CTR is a data warehouse composed of data sets describing events that occur to individual casualties from the point of injury through the medical chain of evacuation, and on to long-term rehabilitative outcomes. A total of 682 WIA patients were extracted and analyzed to project the PC streams for OIF-2. As more data are compiled from the CTR, they will be incorporated into the PCOF tool to refine OIF-2 estimates.

Estimating the PC Streams From OIF-1

Although all data sets were used in estimating the patient streams for the four operations shown in Table 1, this section illustrates how the patient stream was derived for OIF-1. Projecting the PC code percentages from OIF-1 required grouping the ICD-9 codes with equivalent PC codes. This was accomplished by grouping PC codes into similar ICD-9 groups. An exception to this methodology was the PC codes for multiple injury categories, which are based on the anatomical distribution of the injuries. Table 2 shows the proposed categorization of PC code categories based on ICD-9 groupings. Using this method, 95% of the Marines and 90% of the Army primary diagnoses mapped to the PC codes' proposed trauma categories.

Table 1. Percentage Distribution of Patient Condition Categories Among Selected Combat Operations

Trauma Categories	Vietnam	Mogadishu	OIF-1	OIF-2
Amputations – upper	0.5%	3.6%	1.7%	1.0%
Amputations – lower	1.1%	0.0%	2.3%	0.9%
Burns	1.4%	2.4%	3.2%	2.3%
Intracranial injuries (concussions)	3.5%	2.4%	2.3%	2.6%
Crush injuries	0.0%	0.0%	1.6%	0.2%
Dislocation	0.1%	0.0%	2.0%	0.2%
Fractures	12.8%	8.3%	22.7%	8.7%
Sprains/strains	1.3%	3.4%	6.3%	1.8%
All wounds/single/multiple	78.0%	79.9%	54.6%	78.1%
Hearing impairment	0.8%	0.0%	2.4%	3.4%
Visual disturbances	0.0%	0.0%	0.8%	0.3%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

OIF, Operation Iraqi Freedom.

Table 2. Primary ICD-9 Diagnostic Categories for US Army and Marine Corps WIA Casualties During OIF, March–August 2003

WIA PC Categories	ICD-9 Groups	Army	Marines
Amputations	885-887 & 895-897	3.9%	3.8%
Burns	940-949	4.9%	3.0%
Crushing	925-929	1.7%	1.5%
Dislocation	830-839	1.2%	1.9%
Fractures	800-829	20.2%	21.1%
Intracranial	850-854	0.8%	2.3%
Sense – ear	384, 385, 388, 389	5.9%	2.3%
Sense – eye	368, 369	2.5%	0.8%
Sprain	840-848	6.5%	6.0%
Musculoskeletal	717, 724, 727		
Wound (excludes amputations)	860-897	41.6%	51.9%
Total		**89.2%**	**94.6%**
Did not map to a PC category			
Other injuries	960-998	3.4%	1.5%
Other diseases	001-799	2.7%	1.1%
Missing	blank	2.2%	1.9%
E-code (cause of injury code)	E-codes	2.5%	1.1%
Total		**10.8%**	**5.4%**

ICD-9, *International Classification of Diseases*, 9th Revision; WIA, wounded in action; OIF, Operation Iraqi Freedom; PC, patient condition.

In an effort to combine the distributions for the Marines and Army, the chi-square test was used to determine if the trauma category distributions were related to service. The results indicated a significant difference in distributions of trauma category percentages between the two service branches ($X^2 = 22.74$, df = 11, $p < .019$). Although the overall trauma distributions varied by service, some of the individual trauma categories by anatomical location did not vary. Specifically, two major trauma categories, open wounds and fractures, were compared by anatomical location between the Marines and the Army. The chi-square tests indicated that the overall distribution of anatomical locations was not related to service, which implied that the frequency distribution of the location of the wound or fracture was similar for a Marine or soldier.

Since the anatomical location distributions for wounds and fractures were not related to service, the distributions were combined, resulting in larger sample sizes for each cell, thereby reducing the margins of error. This approach was used for all trauma categories, although chi-square tests were not performed on the other trauma categories due to insufficient sample sizes for each cell.

The percentage or probability of a PC code was calculated by estimating the trauma category and the anatomical location. This was accomplished by applying the multiplication rule for independent events, which determines the probability that two events, A and B, both occur.

The multiplication rule follows from the definition of conditional probability where:
P (A) = probability that event A occurs
P (B) = probability that event B occurs
P (A∩B) = probability that event A and event B occur
P (A | B) = the conditional probability that event A occurs given that event B has occurred already
P (B | A) = the conditional probability that event B occurs given that event A has occurred already

For independent events, the rule simplifies to the probability of the joint events A and B equaling the product of the individual probabilities for the two events or $P(A \cap B) = P(A) * P(B)$.

For example, calculating the probability of dislocation of the shoulder for Marines was derived by the multiplying the overall percentage of dislocations among Marines (1.9%; Table 3) and the percentage of dislocated shoulder injuries (82%; Table 4). This resulted in:

*P (PC 64 Dislocation of the shoulder) = 1.9% * 82% = 1.56% or 0.0156.*

Table 3. OIF-1 Trauma Template for Marine Corps Battle Casualties, Grouped by Proposed PC Categories

Patient Condition Groupings	***N***	**Percentage**
Amputations – upper	5	1.7%
Amputations – lower	6	2.3%
Burns	9	3.2%
Crushing	4	1.6%
Dislocation	5	1.9%
Fracture	60	22.7%
Open (60%)		13.6%
Closed (40%)		11.1%
Hearing impairment	6	2.4%
Intracranial	6	2.4%
Miscellaneous	2	0.7%
Sprain/Strains	16	6.2%
Wounds	116	54.6%
Single (80%		43.7%
MIW (20%)		10.9%
Visual disturbances	2	0.8%
Total	**266**	**100.%**

OIF, Operation Iraqi Freedom, Major Combat Phase; PC, patient condition; MIW, multiple injury wounds.

Table 4. OIF-1 PC Trauma Categories by Anatomical Location Frequency Distributions

Amputations – upper	**%**	**Total**
Arm	50.0%	0.85%
Hand	50.0%	0.85%
	100%	**1.7%**
Amputations – lower		
Above knee	5.0%	0.12%
Foot	53.0%	1.22%
Knee	42.0%	0.97%
Pelvis	0.0%	0.00%
	100%	**2.3%**
Burns		
Head	41.0%	1.31%
Lower extremity	21.0%	0.67%
Trunk	0.0%	0.00%
Upper extremity	38.0%	1.22%
	100%	**3.2%**
Crushing injuries		
Arm	29.0%	0.46%
Leg	71.0%	1.14%
	100%	**1.6%**
Dislocations		
Elbow	18.0%	0.34%
Fingers	0.0%	0.00%
Shoulder	82.0%	1.56%
Toes	0.0%	0.00%
	100%	**1.9%**
Sprains/Strains		
Ankle	32.0%	1.98%
Back	14.0%	0.87%
Hand/wrist/fingers	8.0%	0.50%
Knee	46.0%	2.85%
	100%	**6.2%**
Multiple injury wounds		
Abdomen/colon	2.0%	0.22%
Abdomen/limbs/colon	25.2%	2.75%
Abdomen/pelvis	1.0%	0.11%
Abdomen/pelvis/limbs	18.0%	1.96%
Chest/abdomen/organ	12.0%	1.31%
Chest/limbs/fracture	12.2%	1.33%
Chest/upper limbs	13.0%	1.42%
Head/abdomen	7.0%	0.76%
Head/chest	2.3%	0.25%
Head/limbs/amputation	7.3%	0.80%
	100%	**10.9%**

Open fractures	**%**	**Total**
Facial, excluding mandible	1.3%	0.18%
Femur	11.5%	1.56%
Foot/ankle	12.8%	1.74%
Hand/finger	17.9%	2.43%
Humerus	10.3%	1.40%
Knee	1.3%	0.18%
Mandible	3.8%	0.52%
Pelvis	1.3%	0.18%
Radius/ulna	9.0%	1.22%
Skull	1.3%	0.18%
Spine	1.3%	0.18%
Tibia/fibula	28.2%	3.84%
	100%	**13.6%**
Closed fractures		
Clavicle	4.1%	0.46%
Facial, excluding mandible	3.1%	0.34%
Femur	10.3%	1.14%
Foot/ankle	26.8%	2.97%
Hand/finger	12.4%	1.38%
Humerus	1.0%	0.11%
Knee	1.0%	0.11%
Mandible	5.2%	0.58%
Pelvis	1.0%	0.11%
Radius/ulna	5.2%	0.58%
Rib	2.1%	0.23%
Skull	3.1%	0.34%
Spine	8.2%	0.91%
Tibia/fibula	16.5%	1.83%
	100%	**11.1%**
Wounds		
Abdomen	6.0%	2.62%
Buttocks	3.4%	1.49%
Eye	6.2%	2.71%
Face/neck	9.3%	4.06%
Foot/ankle/toe	6.4%	2.80%
Forearm/upper arm	14.0%	6.12%
Genitals	0.3%	0.13%
Hand/finger	5.7%	2.49%
Head	2.9%	1.27%
Leg	28.6%	12.50%
Shoulder	4.4%	1.92%
Shrapnel (multiple)	4.2%	1.84%
Thorax	8.6%	3.76%
	100%	**43.7%**

OIF-1, Operation Iraqi Freedom, Major Combat Phase; PC, patient condition.

Although PC code 64 was a straightforward calculation P (64) = *(trauma % * anatomical location %),* many PC codes have multiple PCs that correspond to a single "traumatism by location" combination. For example, in the burn categories shown in Table 5, the PC code schemata show 6 individual PCs that correspond to this particular "traumatism by anatomy" combination (burns to the upper extremity; PCs 75–80). These PC codes differ by total body surface area (TBSA) and severity of the burn. The frequency distribution proportions of PCs 75–80 were derived by the Defense Medical Standardization Board (DMSB) subject matter expert panel. These proportions are applied to the overall percentage by "burns to the upper extremity" to determine the individual percentages for PC codes 75–80 (Table 5). This process needed an additional step to calculate the PC codes, which can be summarized as:

*PC = Trauma % * Anatomical location %.* DMSB frequency %*

This same strategy was employed wherever there were multiple PCs for a single traumatism by anatomical location combination. With the addition of body armor and new medical capabilities, the DMSB proportions estimation needs to be reevaluated.

Table 5. Defense Medical Standardization Board PC Code Distribution by Severity of Burns to the Upper Extremity

PC Code	Description	%	DMSB Proportions	Total
75	Burn/superficial/upper/10–20% TBSA	1.22%	11%	0.13%
76	Burn/superficial/upper/0–10% TBSA	1.22%	11%	0.13%
77	Burn/partial thickness/upper/10–20% TBSA	1.22%	30%	0.37%
78	Burn/partial thickness/upper/0–10% TBSA	1.22%	20%	0.24%
79	Burn/full thickness/upper/10–20% TBSA	1.22%	20%	0.24%
80	Burn/full thickness/upper/0–10%	1.22%	8%	0.10%
			100%	1.22%

PC, patient condition; DMSB, Defense Medical Standardization Board; TBSA, total body surface area.

Generating Patient Streams for Major Contingency and Stability and Support Operations Using Traumas Resulting From Causative Agents

The second approach to estimating patient streams enables medical planners to project patient streams for MCO and SASO by estimating the trauma categories and anatomical locations that result from the causative agents. This approach provides the capability to forecast patient streams by selecting the specific agents that US forces expect to encounter. The process of developing a patient stream distribution by causative agent involved determining the appropriate agent categories and then calculating the percentage distributions of traumatism categories by anatomical location for each causative agent.

Methods

Causative agents used against US forces from World War II, Korea, Vietnam, Operation Desert Storm during the Gulf War, Mogadishu, OIF-1, and OIF-2 were examined, to provide insight into the varied weaponry used in MCO and SASO operations.[11–15] OIF-2 data were extracted from the CTR, accounting for 682 WIA casualties from March–December 2004. Data were extracted from medical records and data sets documenting casualty admissions of previous combat operations, and were analyzed by specific wounding agent.[11–13] The data shown in Table 6 identify the causative agent distributions used against US forces from previous operations.

Estimating the Scenarios by Causative Agents

The first step in estimating PC streams for MCO and SASO scenarios was to estimate the causative agents that will be used against US forces. Based on the data from previous combat operations, causative agent categories were classified into seven groups: small arms, rockets/bombs, artillery shells, land mines/booby traps, grenades/rocket-propelled grenades (RPGs), improvised explosive devices (IEDs), and moving vehicle accidents (MVAs)/falls. Slight variations from the historical data shown in Table 6 resulted in fragment and shrapnel weaponry counts being averaged into the other categories, land mines and booby traps just called land mines, and other or unknown counts omitted. These assumptions led to the estimation of the causative agents for a variety of operational tempos shown in Table 7.

Major Contingency Operations

The World War II, Korea, Desert Storm, and OIF-1 data were classified as MCO. The causative agents from these operations were averaged to estimate the causative agents that can be expected for MCO. In addition, an MCO scenario for desert terrain was estimated by averaging the causative agents used during Desert Storm and OIF-1.

Stability and Support Operations

The Vietnam, Mogadishu, and OIF-2 combat operations were classified as SASO scenarios. An overall average of these operations was used to estimate the causative agents that can be expected for a likely SASO scenario. In addition, SASO scenarios were estimated for urban and jungle environments. Mogadishu and OIF-2 were used to estimate an urban SASO scenario, and the Vietnam operation was used to estimate a jungle SASO scenario. The shrapnel/fragment percentages from Vietnam were counted as IED for estimating a jungle SASO scenario.

Table 6. Causative Agent Distributions From Historical Combat Operations

Causative Agent Categories	WW II	Korea	Vietnam	Desert Storm	Mogadishu	OIF-1	OIF-2
Small arms count	120,445	13,171	21,156	12	39	70	132
Percentage	20.1%	27.4%	26.9%	10.0%	52.7%	25.1%	19.4%
Rockets/bombs count	15,460	6,096	1,827	Unk	0	Unk	Unk
Percentage	2.6%	0.1%	2.3%	*	0.0%	*	*
Mortars/artillery shells count	340,651	5,045	10,339	Unk	Unk	40	83
Percentage	56.8%	50.3%	13.1%	*	*	14.3%	12.2%
Grenades/RPGs count	14,429	21,002	5,467	Unk	11	39	62
Percentage	2.4%	9.1%	6.9%	*	14.9%	14.0%	9.1%
Land mines/booby traps count	23,529	26,270	21,644	6	0	11	15
Percentage	3.9%	3.7%	27.5%	5.0%	0.0%	3.9%	2.2%
Shrapnel/fragment count	Unk	759	12,477	36	14	40	106
Percentage	*	1.6%	15.8%	30.0%	18.9%	14.3%	15.5%
Other and unknown count	85,210	72,343	5,846	66	10	59	46
Percentage	14.2%	7.9%	7.4%	55.0%	13.5%	21.1%	6.7%
IED count	0	0	0	0	0	20	238
Percentage	0.0%	0.0%	0.0%	0.0%	0.0%	7.2%	34.9%
Total number of WIA casualties	599,724	13,171	78,756	120	74	279	682
Percentage	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

WW II, World War II; OIF, Operation Iraqi Freedom; Unk, unknown; RPGs, rocket-propelled grenades; IED, improvised explosive device; WIA, wounded in action.

Table 7. Estimated Distribution of Causative Agents Used for Various Operation Tempos

Operational Tempo	Small Arms	Rockets/ Bombs	Artillery Shells	Land Mines	Grenades/ RPGs	IEDs	MVAs / Falls	Total
MCO Overall	21%	1%	41%	4%	6%	2%	25%	100%
MCO Desert	18%	5%	24%	4%	7%	4%	38%	100%
SASO Overall	33%	1%	8%	10%	10%	29%	9%	100%
SASO Urban	36%	0%	7%	1%	12%	34%	10%	100%
SASO Jungle	27%	2%	13%	28%	7%	16%	7%	100%

RPGs, rocket-propelled grenades; IEDs, improvised explosive devices; MVAs, moving vehicle accidents; MCO, major contingency operations; SASO, stability and support operations.

Causative Agent Categories

After determining the causative agents, the trauma distributions that resulted from the causative agents were estimated. Percentage distributions for the traumatism categories were reviewed for the operations shown in Table 6, excluding World War II and Korea, and used to estimate the percentage distributions shown in Table 7. These categories were selected based on similar research efforts correlating causative agents and the expected traumatism categories that resulted.[11–13]

Small Arms

Small arms wounding agent data were typically the most frequent and reliable of all the causative agent data available, and were usually reported as gunfire or bullets. The small arms category consists of weapons such as pistols, assault rifles, and machine guns. The recent data from Mogadishu and OIF were primarily used to reflect the advances in protective gear.

Rockets and Bombs

The rockets and bombs category includes those munitions dropped or launched from aircraft by their own propulsion systems. These types of weaponry are used in large-scale operations or MCO. Wounding data from the Vietnam operation were used for estimating the traumas resulting from rockets and bombs.

Artillery Shells (Land-Based Artillery)

The artillery shells causative agent data consisted of wounds caused by land-based artillery, such as mortars, howitzers, tanks, armored vehicles, and other ground-delivered artillery. Typically these weapons yield large fragment and penetrating types of injuries. Wounding data from OIF and Vietnam were used to estimate the anatomical location distributions by trauma category for artillery shells. Forty casualties from OIF-1 and 87 casualties from OIF-2 were identified and analyzed by traumatism and associated anatomical location.

Land Mines

The land mines category was based on all types of land mines and booby traps. The percentage of traumatic amputations resulting from injuries from land mines was significantly higher than for other causative agents, and these occurred predominantly to the lower extremities.[13] Other studies have classified antipersonnel land mine injuries into severity patterns, and as either pull-action or pressure-activated.[16] However, sufficient data were not available for the present study to make a distinction between severity patterns or the different types of land mines. Booby trap data were also classified into the land mine category. Over 20,000 casualties during Vietnam were wounded by land mines or by booby traps. These data were primarily used in estimating the anatomical location distributions by trauma category for the land mines category.

RPGs and Grenades

The RPGs/grenades category comprised all types of grenades, including rocket-propelled grenades. RPGs were predominately used in the Mogadishu raid and in the SASO phase of OIF. This type of weaponry is often used in close-quarters fighting. Currently CTR data are being coded into ICD-9 diagnoses, which will provide the needed accuracy for mapping the ICD-9 diagnoses into PC codes.

Improvised Explosive Devices (IEDs)

Due to the number of injuries resulting from IEDs, a new category was included for this type of weaponry. IEDs have been the most-used causative agents against US forces in the SASO phase of OIF (~35%). IED wounding data were extracted from the CTR, and were coded and grouped by the textual accounts of the injury and by provider notes. Currently, CTR data are being coded into ICD-9 diagnoses, which will provide the needed accuracy for mapping the ICD-9 diagnoses into PC codes.

MVAs and Falls

This category primarily included blunt traumas resulting from moving vehicle accidents and falls. A large percentage of concussions and sprains/strains were due to blunt trauma-related injuries. The traumas resulting from this category were obtained from OIF-1 databases. Twenty-six casualties injured in MVAs and 18 casualties from falls were used to estimate the trauma percentages and anatomical location breakdowns.

Table 7. Estimated Trauma Percentage Distributions by Causative Agents

Trauma Categories	Small Arms	Rockets/ Bombs	Artillery Shells	Land Mines	Grenades/ RPGs	IEDs	MVAs/ Falls
Amputations, upper	1.1%	3.8%	1.4%	2.2%	2.8%	0.8%	0.8%
Amputations. lower	0.3%	3.4%	1.5%	6.0%	2.1%	0.8%	0.9%
Burns	0.3%	8.7%	0.9%	4.0%	5.5%	2.3%	2.8%
Intracranial injuries	1.5%	1.5%	2.2%	2.0%	2.1%	3.5%	8.0%
Crushing injuries	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	3.0%
Dislocations	1.5%	3.3%	0.0%	0.0%	2.5%	0.4%	7.2%
Fractures	27.5%	20.3%	27.3%	24.6%	14.5%	9.1%	16.5%
Sprains/strains	0.5%	2.0%	7.1%	3.8%	2.5%	1.1%	36.0%
Wounds	67.0%	53.5%	55.6%	53.9%	63.6%	75.8 %	24.5%
Hearing impairment	0.0%	1.7%	2.5%	2.5%	1.9%	5.0%	0.0%
Visual disturbances	0.0%	1.8%	1.5%	1.0%	2.5%	0.0%	0.0%
Miscellaneous	0.3%	0.0%	0.0%	0.0%	0.0%	0.8%	0.3%
Total	100.0	100.0	100.0	100.0%	100.0%	100.0	100.0%

RPGs, rocket-propelled grenades; IEDs, improvised explosive devices; MVAs, moving vehicle accidents.

Estimating the Trauma Distributions by Causative Agents

After the overall causative agent distribution was determined, the last step was to estimate the traumatism categories by anatomical location for each causative agent category. The traumatism categories were selected to correspond to ICD-9 categories, since hospitalization data are usually reported in this nomenclature to allow the PC codes to be easily mapped. Data by each causative agent were grouped by trauma and anatomical location distributions shown in Table 8.

Table 8. Estimated Percentage Distribution of Anatomical Locations by Trauma Type and Mechanism of Injury

Traumatism by Anatomical Location	Small Arms	Rockets/ Bombs	Artillery Shells	Land Mines	Grenades/ RPGs	IEDs	MVAs/ Falls
Amputations							
Lower	35.9	61.6	51.6	83.9	59.3	0.0	64.2
Upper	64.1	38.4	48.4	16.1	40.7	100.0	35.8
Burns							
Head/face	16.6	21.4	44.4	64.0	33.3	22.2	45.8
Lower	16.6	7.1	11.1	2.0	0.0	0.0	6.0
Thorax	16.6	28.6	44.4	16.0	50.0	0.0	26.2
Upper	50.0	42.9	0.0	18.0	16.7	77.8	22.0
Dislocations							
Elbow	14.3	0.1	0.1	0.1	0.1	18.0	11.1
Wrist	28.6	0.1	0.1	0.1	0.1	0.0	0.1
Shoulder	42.9	97.7	97.7	88.9	0.1	82.0	83.3
Fingers	14.3	0.1	0.1	11.0	97.3	0.0	5.6
Fractures							
Face	7.0	4.0	11.9	9.4	10.0	6.3	7.9
Femur	17.9	14.0	8.5	7.8	4.4	3.0	10.6
Foot/toe	5.2	2.0	5.8	6.9	6.7	0.0	7.6
Hand/finger	8.2	10.0	15.0	9.8	16.7	21.3	11.4
Humerus	12.4	4.0	8.1	5.6	6.7	6.2	9.0
Knee	0.8	6.0	0.8	2.3	1.1	0.0	3.7
Jaw	0.7	2.0	2.7	3.1	2.2	6.2	3.2
Pelvis	2.5	0.0	0.8	0.7	2.2	0.0	1.3
Radius/ulna	14.0	14.0	16.7	16.5	20.0	30.5	14.7
Ribs	4.0	2.0	1.2	1.7	1.1	0.0	2.4
Skull	2.1	12.0	6.0	4.2	7.8	2.9	5.0
Shoulder	4.1	6.0	2.1	1.5	1.1	0.0	1.8
Spine	4.0	4.0	2.5	4.7	2.2	0.0	3.8
Tibia/fibula	17.2	20.0	18.1	25.8	17.8	23.6	17.9
Sprains/strains							
Ankle	23.1	100.0	40.6	25.8	33.3	20.0	41.8
Back	53.8	0.0	34.4	64.5	50.0	60.0	44.3
Knee	15.4	0.0	21.9	9.7	16.7	0.0	12.7
Wrist	7.7	0.0	3.1	0.0	0.0	20.0	1.1
Open wounds							
Abdomen	1.9	0.9	0.8	2.4	1.7	3.2	3.6
Buttocks	3.7	3.7	3.6	2.9	3.7	3.2	3.1
Eye	0.3	0.9	1.1	3	2.9	4.9	2.2
Face/neck	5	12.1	9.3	9.5	9.5	17.4	7.9
Foot/ankle/toe	4.5	3.3	2.7	2.1	1.9	3.2	4.4
Forearm	25.3	23.4	26.1	21.9	20.5	16.6	18.5
Genitals	0.4	0.9	0.6	0.4	0.7	0.4	0.5
Hand/finger	5.2	4.2	6.3	4.3	5.3	8.9	5.8
Head	1.8	1.9	1.8	3.3	1.5	7.3	2.8
Leg	36.1	36	36.3	37.4	37.6	21.5	36.1
Shoulder	0.3	5.1	4.6	5.1	5.8	7.7	7.6
Shrapnel	8.9	3.3	5.5	4.5	5	5.7	5.3

Thorax	6.6	4.3	1.5	3.3	3.9	0	2.3

RPGs, rocket-propelled grenades; IEDs, improvised explosive devices; MVAs, moving vehicle accidents.

Patient Condition Occurrence Frequency (PCOF) Estimation Tool

The development of the PCOF tool provides the necessary calculations and adjustments needed to refine the PC streams. Incorporating additional information as it becomes available will become a simpler task. This patient estimation tool was developed to provide quantitative approaches that easily generate patient streams. The first approach provides scenarios based on previous combat operations, and the second approach provides scenarios by operational tempo for MCO and SASO scenarios. In addition, any combination of these two approaches can be used to create various patient streams by adjusting the overall input percentage of each.

Patient Streams From Previous Combat Operations

The user can select various scenarios from the drop-down combo box, which will reflect wounding patterns evidenced from that particular operation (Figure 1). To generate a unique scenario, users must enter the trauma percentages for each of the 12 trauma categories and make sure that the percentages equal 100%. Then within each trauma category, they must enter anatomical location distributions, again totaling the percentages to 100%. In addition, users can still edit these scenarios, but the results must be saved into another file. The drop-down scenarios will always provide the same results when selected and will overwrite all current entries.

Patient Streams by Operational Tempo

The other approach to generating a patient stream is to select the patient streams by operational tempo. Baseline distributions of traumas by causative agent are currently provided, which will allow medical planners to estimate patient streams based on mix of weaponry and for MCO and SASO tempos. Users can choose from these selections in the drop-down combo box that reflect the wounding patterns evidenced from that particular operational tempo based on the mix of weaponry. In addition, users may also enter their own mix of trauma and anatomical location wounding distributions organized by causative agent by simply varying these percentages.

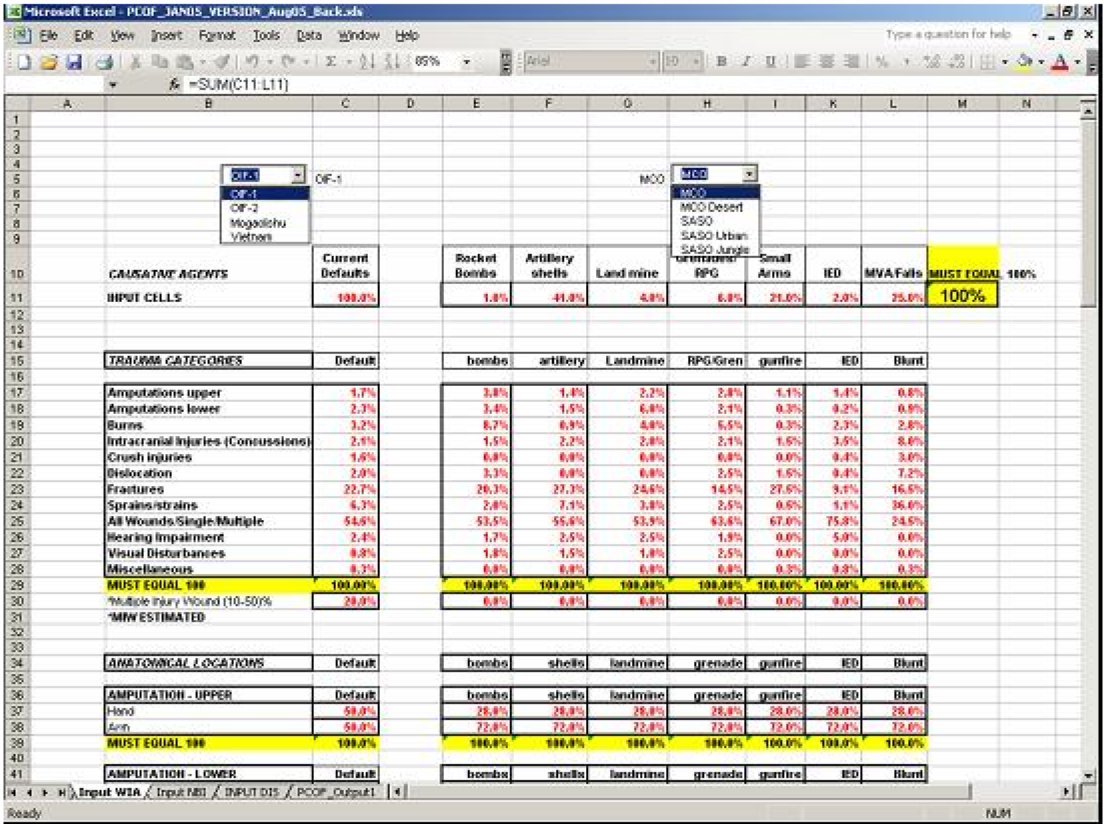

Figure 1. The PCOF tool features drop-down menus for selecting PC code patient streams.

Summary

Estimates of the likely distribution of medical admissions by PC code are required to ensuring adequate programming of resources to meet the medical needs of combat operations. A quantitative process to accurately estimate patient streams is essential for modeling and simulation programs to project resources for current and future combat operations. The use of computer-aided algorithms will easily generate patient streams for various scenarios and operational tempos for major contingency, stability and support, and global war on terrorism operations.

Updated PC occurrence frequency files will be created for MCO, SASO, and Homeland Defense scenarios. These scenarios are required by the Medical Readiness Review board for assisting in the fiscal year 2007 President's Budget, used in the Strategic Planning Guidance document, and for the Quadrennial Defense Review recommendations. Lastly, this information will be provided to the Medical Resources, Plans, and Policy Division (N931) and the Joint Staff Logistics J4 Division.

Future work will develop the patient streams for DNBI casualties and continue to refine the estimations as more CTR data become available. Subsequently, these patient streams will then be incorporated into casualty rate projection tools that estimate the expected number of casualties. The magnitude and composition of the anticipated patient load is essential for medical planning and resource projections. Combining the expected PC code distributions with the projected overall WIA and DNBI incidence rates will allow planners to more accurately project medical resource requirements. Incorporation of this PC-forecasting capability into MAT, ESP, and TML+ will facilitate corollary projections of staffing demands, requisite equipment, and needed medical supplies tailored to specific patient streams.

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14. ABSTRACT (maximum 200 words)

Modeling and simulation applications require accurate estimations of the number and type of injuries and illnesses. These estimates, called patient streams, include projections of the patient condition (PC) code frequencies needed for estimating medical resources for various types of military operations. They are the diagnostic nomenclature that modeling and simulation applications use. Currently, no quantitative process has been developed to estimate these patient streams.

The objective of this research was to develop a methodology that links hospitalization data to the PC code nomenclature. Two approaches to estimate PC code patient streams were addressed. The first approach linked trauma and anatomical location percentages to PC codes for selected operations. In the second approach patient streams were estimated from the traumas resulting from the causative agents expected to be used by enemy forces. Data spanning from the Vietnam operation to Operation Iraqi Freedom were used in deriving the patient streams for both approaches.

Finally, the Patient Condition Occurrence Frequency (PCOF) tool was developed using both quantitative approaches to easily calculate various patient streams that can then be incorporated into planning and logistics models, such as the Medical Analysis Tool (MAT) and the Tactical Medical Logistics planning tool (TML+).

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