Evaluation of Triage Tagging Protocols Using a Synthetic Dataset Representative of Battlefield Injury Profiles

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INTRODUCTON

- Triage tagging protocols are essential for prioritizing patients in mass casualty scenario.
- Several tagging protocols exist, including START, SALT, and BCD Sieve.
- Limited research has compared and assessed protocol performance over time because the data required to assess performance is not easily accessible.
- There is a critical need for a dataset of casualties with the demographics, injury profiles, and vital signs associated with a military population.
- In this work, we created a synthetic representative population and assigned tags (Immediate, Expectant, Delayed, or Minimal) to support the analysis of tagging protocols.
- This open dataset can also be used to evaluate treatment algorithms and training and validation of AI algorithms in decision support medicine.

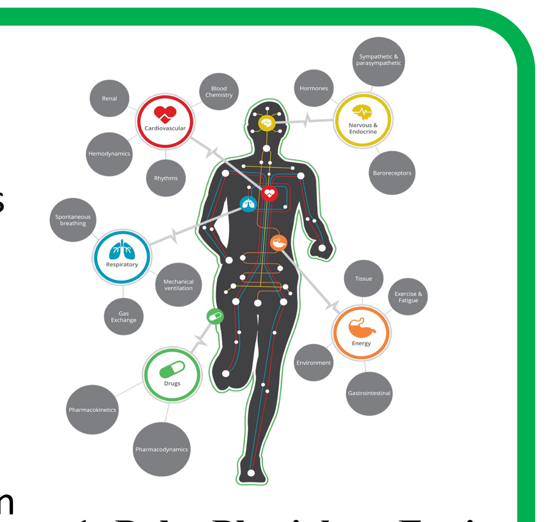

Figure 1: Pulse Physiology Engine

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DISCLAIMER

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METHODS

- We used synthetic reconstruction techniques to generate a population of individuals and injury profiles representative of the statistical composition of the U.S. military and battlefield injuries[1-7] (Figure 2).

Synthetic Population and Injury Generation

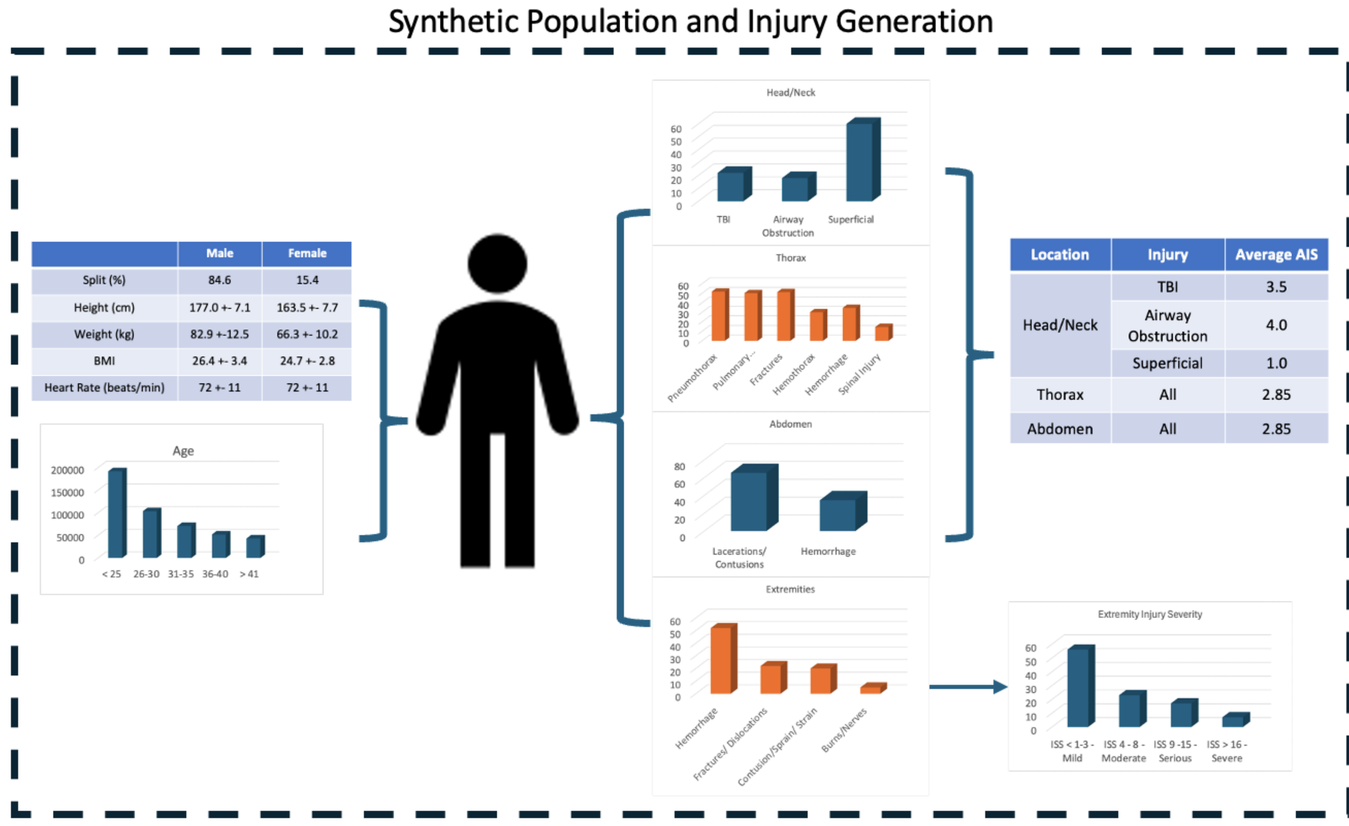


Figure 2: Statistical Representation of Military Population and Injuries

- Each of the casualties in the synthetic population was converted into a patient in the Pulse Physiology Engine (Table 1).

Table 1: Pulse Injury Translation

Injury		Pulse Translation			
Location	**Type**	**Action**	**AIS 1 Severity**	**AIS 6 Severity**	**Compartment**
Head and Neck	TBI	Brain Injury	0.15	1.0	-
		Acute Stress	0.15	0.35	-
	Airway Obstruction	Airway Obstruction	0.15	0.9	-
		Acute Stress	0.15	0.35	-
	Superficial	Hemorrhage [5-15 mL/min]	0.03	0.08	Skin
		Acute Stress	0.15	0.35	-
Thorax	Pneumothorax	Closed Tension Pneumothorax	0.05	0.6	Left\Right Lung
		Acute Stress	0.15	0.35	-
	Pulmonary Contusion	Acute Respiratory Distress Syndrome	0.15	1.0	Left\Right Lung
		Acute Stress	0.15	0.35	-
	Hemothorax	Closed Tension Pneumothorax	0.05	0.6	Left\Right Lung
		Hemorrhage [11-60 mL/min]	0.05	0.10	Muscle
		Acute Stress	0.15	0.35	-
	Hemorrhage	Hemorrhage [15-75 mL/min]	0.02	0.10	Skin and Muscle
		Acute Stress	0.15	0.35	-
	Spinal	Acute Stress	0.2	0.7	-
	Fracture	Acute Stress	0.2	0.7	-
Abdomen	Hemorrhage	Hemorrhage [13-75 mL/min]	0.10	0.25	Spleen
			0.03	0.09	Liver
		Acute Stress	0.15	0.35	-
	Laceration/ Contusion	Hemorrhage [9-40 mL/min]	0.05	0.2	Skin
		Acute Stress	0.15	0.35	-
Extremities	Hemorrhage	Hemorrhage [13-75 mL/min]	0.15	1.0	Right/Left Arm
			0.15	1.0	Right/Left Leg
		Acute Stress	0.07	0.35	-
	Fraction/ Dislocation	Acute Stress	0.2	0.7	-
	Contusion/ Sprain/Strain	Acute Stress	0.2	0.7	-
	Burn/Nerve	Acute Stress	0.2	0.7	-

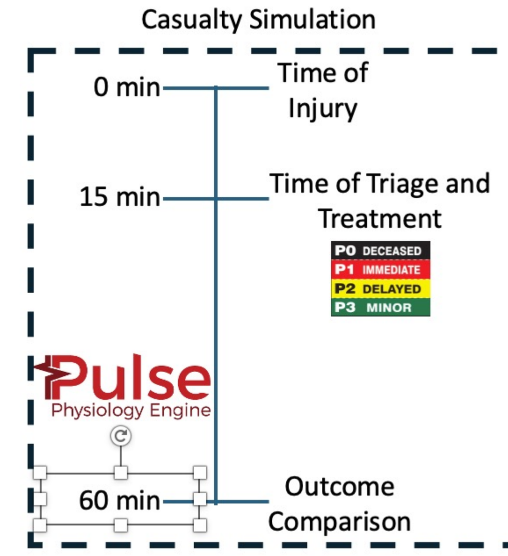


Figure 3: Simulation Timeline

- Each Pulse patient was simulated for 15 minutes, triaged, then simulated for 45 more minutes (Figure 3).
- Three triage protocols (BCD Sieve, SALT, and START) were used to tag the casualties. Table 2 shows the parameters from Pulse used to evaluate the tags.

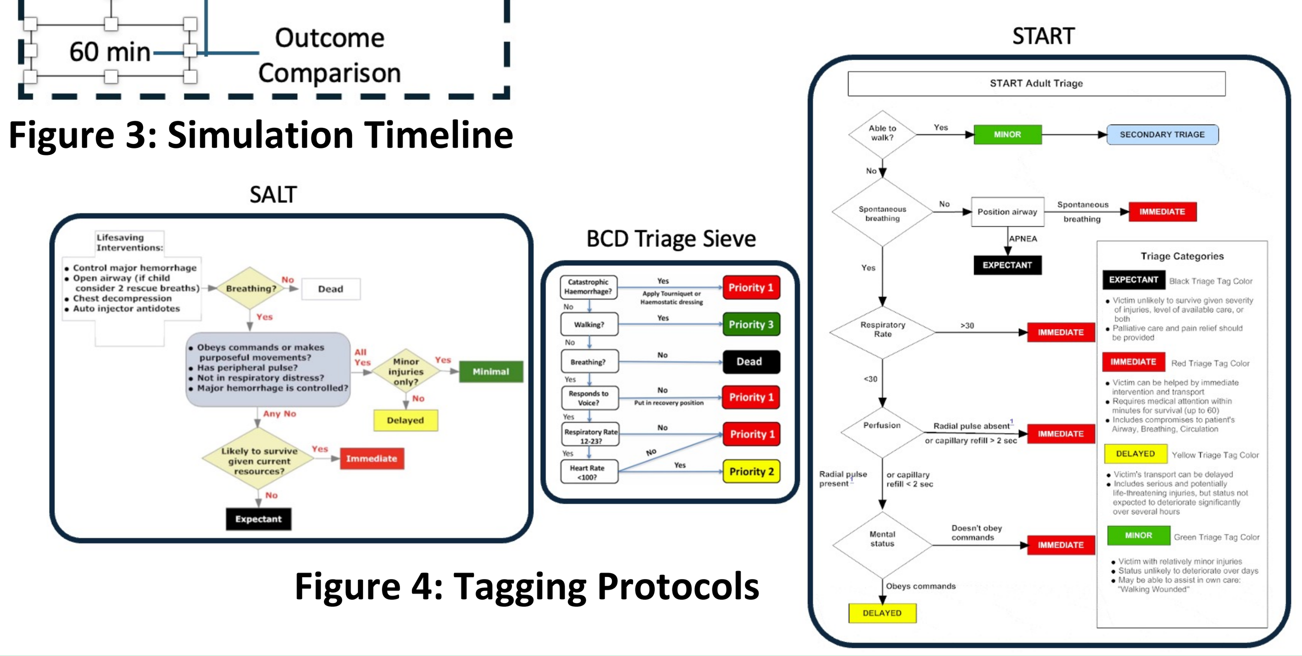
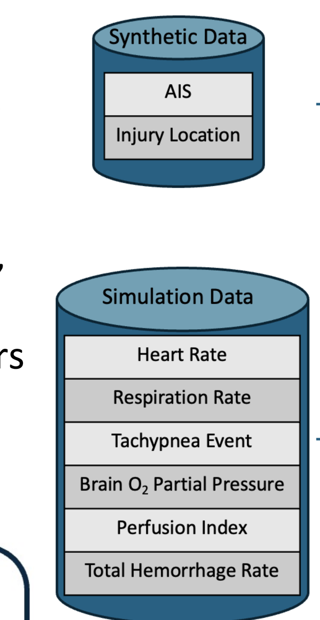


Figure 4: Tagging Protocols



Triage Value	Translation from Input	Description Examples
Heart Rate	= Heart Rate	The casualty has a rapid/slow/normal heart rate.
Respiration Rate	=Respiration Rate	The casualty has a high/low/normal respiration rate.
Breathing	Respiration Rate >= 1 : TRUE Respiration Rate < 1 : FALSE	The casualty is not breathing. Repositioning the airway resulted/did not result in spontaneous breathing.
Capillary Refill	Perfusion Index >= 0.03 : TRUE Perfusion Index < 0.03 : FALSE	The casualty has/does not have normal capillary refill.
Respiratory Distress	Tachypnea Event=TRUE : TRUE Tachypnea Event=FALSE : FALSE	The casualty is in respiratory distress.
Controlled Hemorrhage	Total Hemorrhage Rate < 15 ml/min : TRUE Total Hemorrhage Rate >= 15 ml/min :FALSE	The casualty has a major/minor hemorrhage that was controlled/not controlled.
AVPU	Brain O_2 >= 35 mmHg : ALERT AIS =4 ||25 < Brain O_2 < 35 mmHg mmHg : VERBAL 15 < Brain O_2 < 25 mmHg mmHg : PAIN AIS Severity >= 5 || Brain O_2 < 15 mmHg : UNRESPONSIVE	The casualty is alert/responds to voice prompts/responds to pain stimuli/is unresponsive.
Ambulatory	Injury Location =Extremities && AIS >= 3 : FALSE AIS Severity > 3 || AVPU != Alert = FALSE Otherwise : TRUE	The casualty is ambulatory.

Figure 5: Tagging Assessment

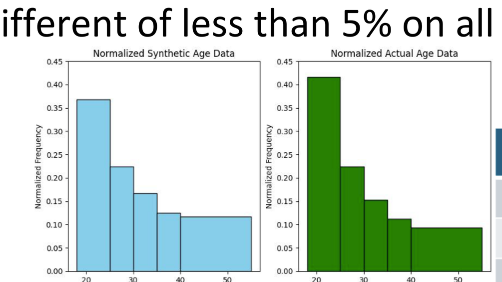
- The Pulse simulation data was used to assess each casualty according to the tagging protocols (Figures 4 and 5).
- The tags for each casualty were then compared for survivability across protocols and injuries.
- A sample dataset can be found by using the QR code (Figure 6).

Sample Dataset

Figure 6: Sample Dataset

RESULTS

- The resulting population size was 10,000 casualties to achieve a percent different of less than 5% on all demographic and injury statistics.



	Synthetic Mean	Literature Mean	Percent Difference	Synthetic SD	Literature SD	Percent Difference
Female Height	163.5	163.5	0.0	7.6	7.7	0.8
Female BMI	24.5	24.7	0.8	2.6	2.8	8.0
Male Height	177.0	177.0	0.0	7.1	7.1	0.0
Male BMI	25.5	26.4	3.6	2.7	3.4	22.9
Heart Rate	72.1	72.0	0.2	-	-	-

Sex	Synthetic	Literature	Percent Difference
Female	16.5	15.4	7.0
Male	83.5	84.6	1.3

Injury Location	Injury Type	Synthetic Distribution	Literature Distribution	Percent Difference	Synthetic Mean Severity	Literature Mean Severity	Percent Difference
Abdomen		6.9	6.9	0.2			
	Hemorrhage	34.3	34.6	0.9	2.86	2.85	0.3
	Laceration/ Contusion	65.7	65.4	0.5	2.9	2.85	1.9
Extremity		48.8	48.4	1.3			
	Burn/Nerve	5.1	5.0	2.4			
	Contusion/ Sprain/Strain	19.7	20.0	1.3			
	Fracture/ Dislocation	22.3	22.0	1.2			
	Hemorrhage	52.9	52.0	1.6			
Head/Neck		35.6	36.2	1.7			
	Airway Obstruction	17.6	18.0	-2.3	4.0	4.0	0.6
	Superficial	60.5	60.0	0.9	1.0	1.0	0.0
	TBI	21.9	22.0	0.6	3.5	3.5	0.0
Thorax		8.7	8.6	1.7			
	Fracture	51.3	51.2	0.2	2.8	2.85	1.2
	Hemorrhage	35.5	34.6	2.6	2.8	2.85	0.3
	Hemothorax	29.7	30.0	0.9	2.9	2.85	0.8
	Pneumothorax	52.0	51.8	0.3	2.8	2.85	0.1
	Pulmonary Contusion	40.3	50.2	0.1	3.0	2.85	3.5
	Spinal	13.7	14.6	6.5	2.9	2.85	2.9

Figure 7: Statistical Comparison of Synthetic Data

- Casualties with a 16 > BMI > 30 were able to stabilize in Pulse. The remaining ~15% were not simulated.
- The survivability of the three triage protocols was for the casualties by looking at each AIS severity level (Figure 8).

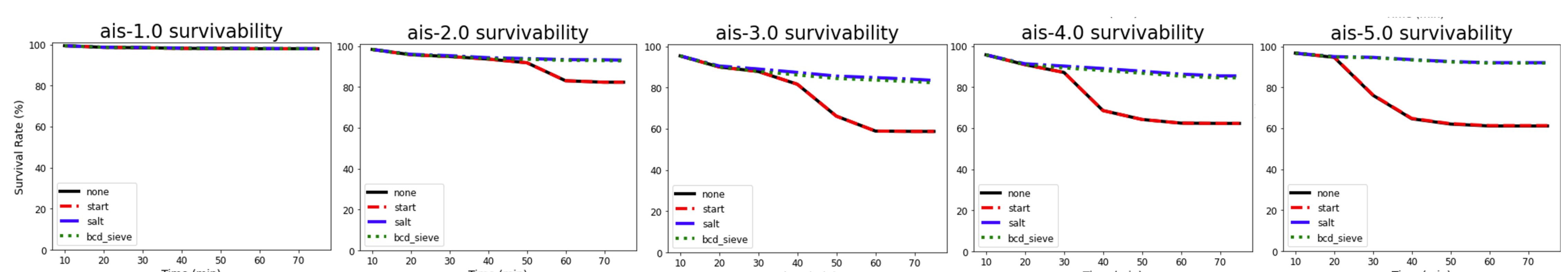


Figure 8: Survivability Comparison

- AIS 6 had zero survivors at the initial triage (15 min).
- SALT had the highest survivability because it recommends airway positioning, hemorrhage treatment, and needle decompression. BCD Sieve does not recommend needle decompression. START does not treat hemorrhage.
- As no treatments were applied after initial triage, START has a low survivability for any hemorrhage casualty.
- The tag distribution was also compared for the three protocols (Figure 9).
- START has a similar number of green and yellow tags for hemorrhage but because it is untreated this does not align with survivability.
- SALT has more green tags because it requires a minor/major decision point that does not necessarily align with vital signs.
- BCD Sieve relies more heavily on the vital sign values, which results in more yellow tags.

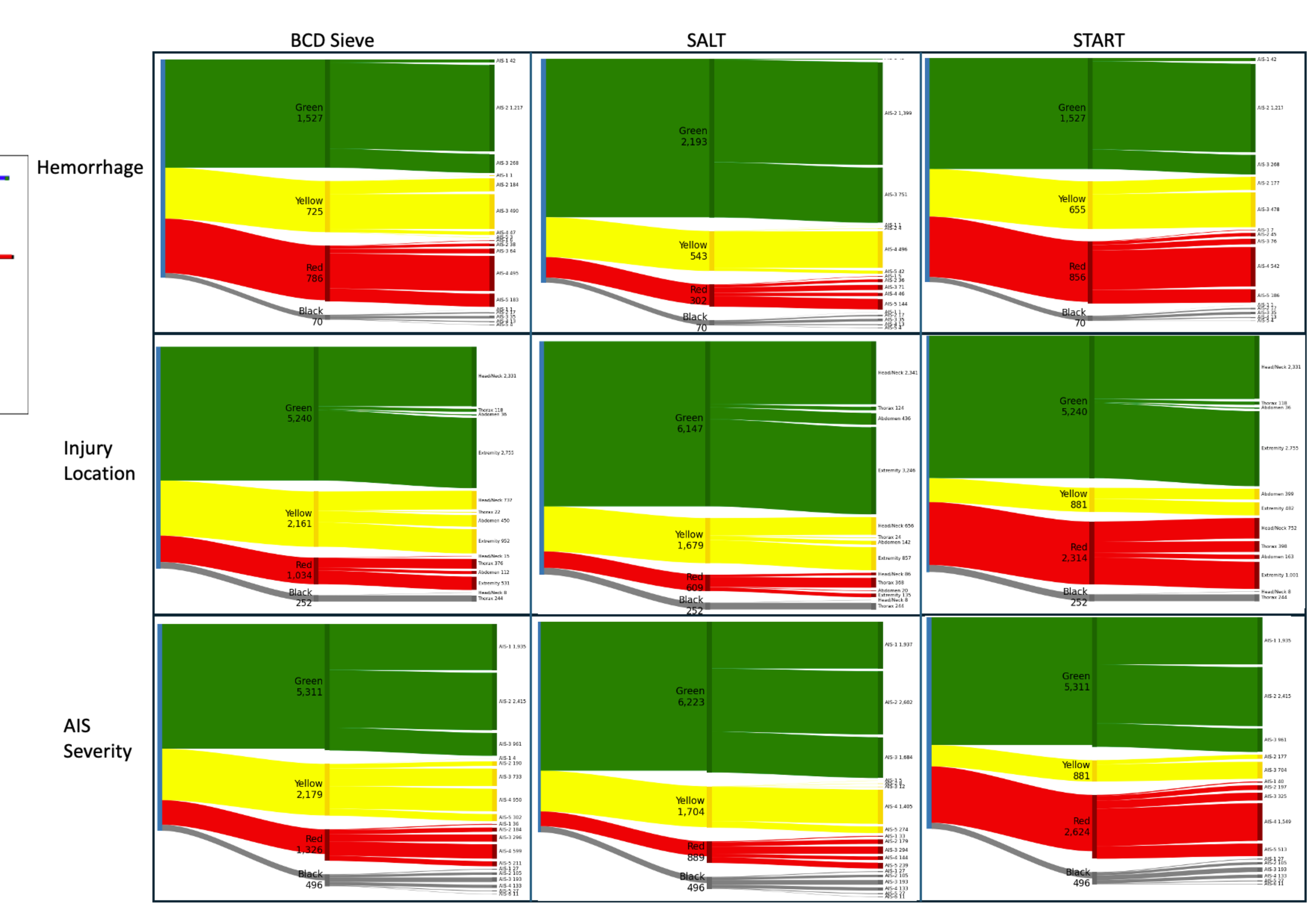


Figure 9: Tag Distributions

DISCUSSION

- This publicly available dataset is the first of its kind and can be used for digital twin modeling, population studies, and model validation and training, including AI and LLM models.
- A limitation of the study is Pulse's inability to model obese patients which led to a failure to generate stable digital twins for 15% of our dataset. We hope to update Pulse to represent a wider range of BMIs in the future.
- Also, the strict protocol implementation (i.e., no hemorrhage treatment for START) and no consideration for available resources (i.e., needle decompression in SALT) was a limitation. Future work will account for available resources, including time, transport, and consumables.
- The dataset is only a representation of Army demographics and an injury profile from previous wars. More branches and access to trauma databases could further inform a larger dataset.

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