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Allocation of Trauma Resources in the State of Ohio:
A Data Driven Approach for Performance Assessment and Benchmarking

ANNUAL PROJECT REPORT

Submitted to

Division of Emergency Medical Services (EMS)
Ohio Department of Public Safety (ODPS)

Submitted by

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Executive Summary

For optimal patient care and resource utilization in trauma, it is vital for EMS agencies to have trauma-specific performance improvement (PI) programs in place. In the state of Ohio, similar to most other states in the U.S., there is not state-wide trauma-PI data or standardized toolkits available at the EMS level. These, if available, could not only help in understanding current EMS practice and trends, but also help in benchmarking the agencies against their peers.

This study, specifically, focused on (i) identifying and assessing scope and potential barriers for trauma-specific PI activities, and (ii) clustering counties based on similarities in trauma-specific EMS capabilities, volume, and PI activities, along with benchmarking them in each cluster based on patient safety measures (i.e., under- and over-triage).

Our multidisciplinary team developed and distributed a voluntary survey to all the EMS agencies throughout the state. For clustering and benchmarking purposes, along with the survey data, we utilized nearly 6,002 patient records from the 2012 data available from the ODPS that comprised of both EMSIRS and Trauma Registry data elements for each patient record. Over- and under-triage errors were calculated using the Injury Severity Score (ISS) method per current literature. Specifically, over-triage (OT) was defined as the proportion of patients with ISS≤15 and were transported to a Level I/II trauma center, while under-triage (UT) was defined as the proportion of patients with ISS>15 and were transported to a Level 3/Non-trauma center (NTC).

Key findings from our study included the following. *First*, of all EMS agencies that responded (338 agencies across 87 counties), 36% do not perform any trauma-specific PI activities, in particular ensuring appropriate documentation for trauma runs, which has been shown vital for trauma patient care and safety. *Second*, there is no standardization on type and frequency of trauma-PI activities among the agencies that offer trauma-PI programs to their employees. For instance, approximately 60% of respondents who offer trauma-PI opportunities suggested that they assess their trauma run-time at least once a month while ~20% respondents conduct this activity either once a year or never do it. Similar pattern was observed for PI review of trauma cases as well. This may suggest that regional or state-level standardization or guidance on the definition and the frequency of trauma-PI activities is lacking. *Third,* thematic analysis revealed that (i) access to county or state EMS data, (ii) consolidation of efforts, (iii) standardization of trauma-PI programs, and (iv) getting feedback from the receiving facility could further help improve trauma-PI programs and activities for EMS providers. *Forth*, EMS agencies appear to cluster around county type (rural vs urban), number of trauma-runs, number of paid vs. voluntary employees, and additional resources provided by EMS

agencies to help with well-being and coping mechanisms for EMS providers. Interestingly, rural counties appear to offer more resources to their EMS providers that can help them manage stress after trauma runs or death of a patient. Further research in evaluating satisfaction and well-being of EMS providers in urban vs. rural counties would be interesting. *Finally*, benchmarking revealed the best performing counties in terms of UT and OT compared to their peers in the same cluster. Such comparison among county-level EMS performance with similar counties (in the same cluster) can unravel new insights that could be used to target cluster-specific interventions to achieve improved outcomes.

In summary, we believe that with the increased frequency of trauma, mass shootings, and other large-scale trauma disasters, it is vital for EMS agencies to conduct trauma-PI activities regularly and keep their skills and procedures current. This means that it is essential for the state and/or regional trauma systems to address any inconsistencies in trauma-PI activities and further elucidate effective measures for the EMS community. Specifically, our work demonstrates which counties in their respective clusters are performing well and identifies those that need further improvement. We strongly believe that our findings would help the state of Ohio in achieving their goal of providing a "Framework for Improving Ohio's Trauma System" that was included in the Ohio EMS 2015 Strategic Plan.

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1. Investigators

Priti Parikh, PhD (Role PI): Priti Parikh is an Associate Professor and Research Director in the Department of Surgery at the Wright State University. She has significant experience and expertise in clinical research, including improving trauma care and systems where she has worked on improving prehospital triage decision in the state of OH, predicting discharge disposition at a point of admission of trauma patients, system analysis of surgical operations, and developing ontologies to answer critical questions. She has over 30 peer-reviewed journal and conference articles with over 40 presentations and talks at local, national and international conferences. She has been a PI or co-I on multiple grants from the state of Ohio and the Veterans Affairs hospitals. More specifically, she has led two recently completed research grants from the state of Ohio that studied the trauma care spectrum in the state and inter-facility transfers that laid the foundation of the proposed work.

Lynne Buckingham, EMT (Role, co-I/consultant): Lynne Buckingham has been working closely with Dr. Priti Parikh and assisting her on several research initiatives, including prehospital trauma care and surgical education. Ms. Buckingham became a certified EMT in August 2016 and has been providing services for a volunteer rescue squad in her home community of Ft. Loramie, Ohio. The territory covers approximately 80-square miles and there are about 13 members. Her team is on call every 3 days for a 12-hour shift. While trauma case volume in this rural community may not be high, the trauma triage training and performance improvement activities are crucial to ensure optimal care for the citizens with very limited trauma resources. Ms. Buckingham was invited to join the team for this project to make sure that her experience in the rural community is well represented to provide a perspective that many may not have experience with.

Brendan Deere, EMT-P (Role, co-I/consultant): Brendan Deere is a paramedic (EMT-P) and currently serves as a Manager of EMS Outreach and Education where he is actively involved in developing new programs and training for EMS providers. He also currently serves as a QI liaison to their Standing Orders Committee where he assisted in the development of regional triage protocols and practices. Moreover, as a QI liaison he also assists in improving overall trauma care and patient outcomes (closely related to the proposed work).

Pratik J. Parikh, PhD (Role, co-PI): For over 9 years, Pratik Parikh (a healthcare systems engineering researcher) and his team have focused on exploring the interdependencies between various healthcare subsystems and identifying alternate methods to improve healthcare system performance. Pratik Parikh collaborates regularly with Miami Valley Hospital, the VA medical centers, Kettering Medical Center, and healthcare researchers at Maine Medical Center (Portland, ME), Boston VA (Boston, MA), Purdue University, and New England Veterans Engineering Research

Center (Boston, MA). He has joint appointments with the Departments of Surgery and Computer Science and has over 50 peer-reviewed journal and conference articles. His recent projects include assessment of triage errors, readmission prediction, inpatient discharge planning, and scheduling staffing and surgeries. His projects have been funded by Federal agencies (e.g., National Science Foundation and the VA) and industry.

2. Study Rationale and Objectives

The primary goal of an efficient and effective trauma system is to provide the right patient the right care, at the right place, and at the right time. Research indicates there is a 25% reduction in deaths for severely injured patients who receive care at a Level I trauma center rather than a non-trauma center [1]. However, not all injured patients can or should be transported to a Level I center. Therefore, Emergency Medical Service (EMS) providers perform field triage to assist in determining the most appropriate level of care needed for the patient. Since the treatment patients receive on the field can significantly alter their outcome, it is vital for any trauma system to continually assess and improve coordination of patient care and outcomes. Further, for viability reasons, it is crucial for trauma systems to optimize their resource utilization and reduce cost burden. This has made essential for EMS agencies to have in place quality and performance improvement programs that rely on key performance indicators to continuously monitor the system's overall performance, resource utilization, and effectiveness of prehospital interventions [2].

For the state of Ohio, it is critical to first understand what level of care each EMS agency provides through what trauma resources, along with the type of performance improvement (PI) programs as drivers to improve trauma care and reduce resources. If such data can be collected, then it will allow the state to compare and benchmark these agencies (or counties) against similar peer groups (per the Joint Commission on the Accreditation of Healthcare Organizations [3]). Benchmarking EMS agencies against similar peer agencies can reveal best practices among top performers in terms of care provision. This will enable the adoption of such best practices not just in that specific peer group, but also potentially across the state.

3. Specific Aims

Following were the specific aims of this study:

- *Aim 1. Identify and assess its scope and potential barriers for trauma-specific PI activities*
  We identified and assessed available state-wide resources and PI training/activities by reaching out to all the EMS agencies and administering an anonymous survey comprising of structured

(close-ended) and unstructured (open-ended) questions on trauma-specific PI activities.

- *Aim 2. Peer-group benchmarking of trauma-specific EMS performance by county*
  Using the data collected in Aim 1, and 6,002 deidentified trauma records for 2012 data available to us by the ODPS, we developed a data analytics-based quantitative method to first cluster counties by EMS capabilities, volume, and PI activities, and then benchmark them within each cluster based on patient-safety metrics (under- and over-triage).

4. Significance

Trauma remains a top 10 leading cause of death in the U.S. and among the top 3 for people <44 years of age [4,5], accounting for 30% of all life-years lost (cancer=16%, heart disease=12%). The resulting economic burden is approximately $671 billion annually, with 192,000 deaths attributed to trauma injuries. It is the most expensive, yet predictable and preventable public safety problem [5].

A state-wide Emergency Medical Services (EMS) system functions to reduce death and disability resulting from trauma primarily through the provision of optimal pre-hospital care and field triage. Since majority of trauma deaths occur in the pre-hospital environment or within 4 hours of the trauma event [6], pre-hospital field triage process becomes extremely important and time sensitive. Optimal match of EMS resources available in a community to each patient's needs is critical to improve trauma patient outcomes. While appropriate resources and training are vital for an EMS agency, it is equally critical to adopt performance improvement (PI) programs to ensure that actual care delivery in a variety of situations (e.g., mass casualty, weather effects) are monitored, discussed, and best practices identified. Data generated through such PI programs and activities help the EMS system in several ways [7]:

- Improving quality, consistency, and patient satisfaction in the region;
- Providing a systematic feedback to EMS agencies to enhance their efficacy;
- Supporting strategies to improve staffing patterns, education, and reimbursement; and
- Assisting the state-wide EMS to define, measure, and analyze their system of care.

The regulations in the state of Ohio (per amended substitute house bill #138) require EMS organizations to implement ongoing peer review and PI programs to improve EMS quality and care [8]. To improve the performance of any healthcare system, benchmarks must be established as emphasized by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) [3]. JCAHO's mission for health care improvement is focused on two most useful types of benchmarking; (i) internal benchmarking that entails comparing peer-groups that perform similar work and who

may be a source of superior practice; and (ii) competitive benchmarking that compares different systems or competitors [9,10].

Studies suggest that to improve EMS or trauma system design and development strategies, statewide benchmarking and sharing of best practices is essential [11]. While benchmarking is now common in health care industries, very limited research and information exists in the EMS domain [12,13]. To our knowledge, establishing benchmarks to improve trauma care using scientific approaches has not yet been studied.

Statewide peer-group benchmarking of trauma-specific EMS resources and trainings based on the group performance would allow the state personnel to appropriately plan, develop, and utilize their trauma system. Due to the nonexistence of a comprehensive baseline assessment of the Ohio Trauma System's resources, proper administration and oversight of the available resources in the system is not possible.

5. Approach

We present below our approach to data collection and analysis (thematic and clustering/benchmarking). This research was approved by WSU's Institutional Review Board.

5.1. Data Collection

Ohio has 88 counties, 38 urban and 50 rural as designated by the state [14]. Across the state, 1,239 EMS agencies provide emergency care to the state's 11.69 million citizens. Both qualitative and quantitative data were collected from these EMS agencies. An anonymous voluntary survey was distributed to chiefs of all EMS agencies. There were both close- and open-ended questions in the survey regarding demographics, capabilities of EMS agencies, volume, and PI activities; see Table 1.

Table 1. Summary of factors considered in this study

Capabilities	PI activities
- EMS vehicles - Volunteer providers - Paid workers - Average response time for an agency in a county to reach the trauma scene - Rural area service - Urban or Rural	- Additional Resources offered to employees *e.g., SMT, CWTC, PRTC, CWDP, LB, CSID, EAP* - What the agency considered trauma performance improvement activities (PI) *e.g., opinion about PI, trauma PI activities* - Barriers related to conducting PI activities *e.g., LOPI, LOFR, LOSFR, TC, FFH, UOTC*
Volume	
- EMS volume handled per year - Area covered	

Note: *SMT = Stress Management Techniques, CWTC =Coping With Trauma Cases, PRTC = Post Run Trauma Counseling, CWDP = Coping With Death of Patient, LB= Life Balance, CSID = Critical Incident Stress Debriefing, EAP = Employee Assistance Program, LOFR = Lack of Financial Resources, LOPI = Lack of Participation or Interest from EMS providers, LOSFR = Lack of Support from Regional or State level Trauma systems, UOTC = Unavailability of Training centers, TC = Time Constraint, FFH = Feedback From Hospitals*

5.2. Data Preprocessing and Analysis

All the survey data were descriptively analyzed and qualitative data (narrative comments) were thematically analyzed using constant comparative method [15]. Figure 1 shows the schematic for the process we followed in clustering and benchmarking the EMS agencies using this survey data. Records with missing data and duplicate entries from the same station within an agency were excluded. Records of stations belonging to the same agency were aggregated into a single record for that agency. Categorical questions with Yes/No answers were transformed into binary variables. Questions about PI, which had a wide range of choices; for the question related to possible barriers to conduct trauma-specific PI activities, the responses such as, e.g., lack of volunteer time and lack of time to train were grouped into a new category and referred to as 'Time Constraint.' The categories for PI were also represented as binary variables for each category. We then conducted a pairwise correlation among these 22 factors to identify if any of these factors was highly correlated with others. Finally, we aggregated the agency-level data into county-level in our further county-specific analysis.

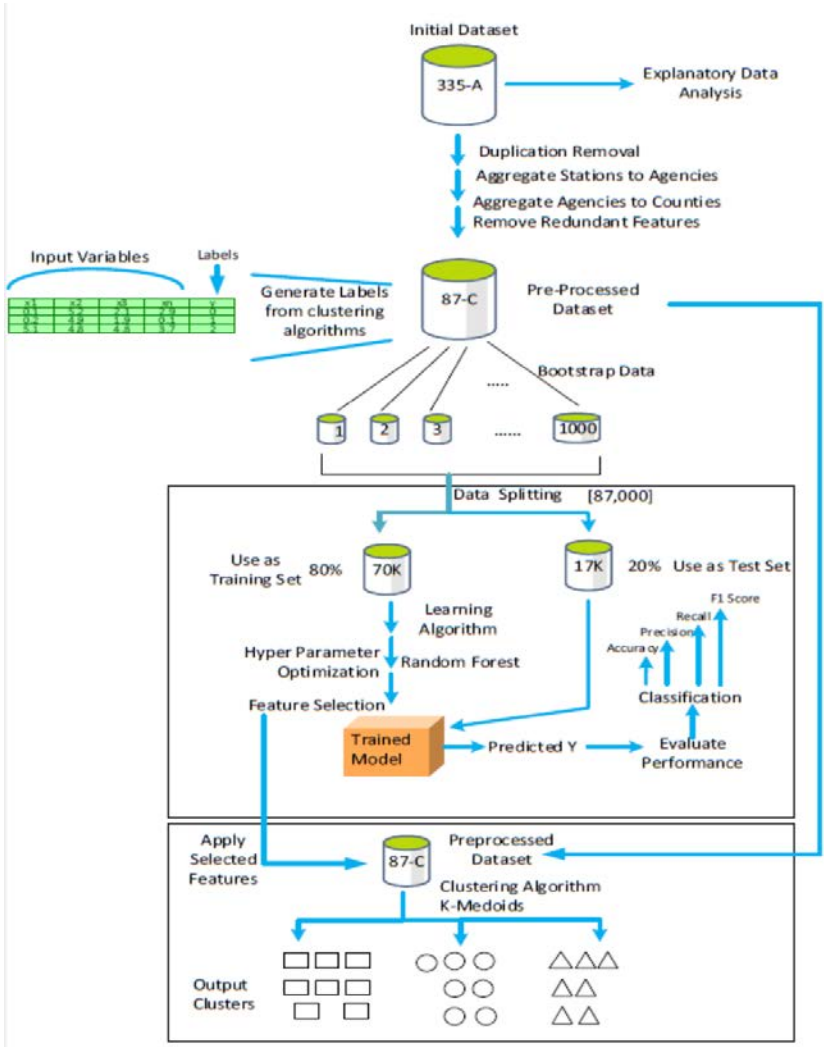


Figure 1. Schematic of the clustering/benchmarking

5.3. Clustering and Benchmarking Approach

To cluster counties, we evaluated three clustering methods: K-means, K-medoids, and CLARANS. We compared all 3 approaches based on (i) Silhouette score, which measures how similar an object

is to its own cluster compared to other clusters, and (ii) Davies-Bouldin score, which measures how well the clustering has been done based on quantities and features inherent to the dataset. Typically, a higher Silhouette and a lower Davies-Bouldin score indicate high-quality clusters. We then (i) determined the top 10 factors through a sophisticated approach (that involved using Random Forest technique), (ii) identified the best number of clusters to group the counties, and (iii) compared and selected the best clustering method (which was K-medoids) based on the Silhouette and Davies-Bouldin scores. The 87 counties were finally grouped into 3 clusters.

Benchmarking of the county performance was done using patient safety measures; we used under-triage (UT) and over-triage (OT) as surrogates. The 2012 EMSIRS and Trauma Registry linked data (6,002 records after removing missing values) available from the Ohio Dept of Public Safety was used for this purpose. We employed ACS recommendations of UT and OT to stratify EMS performance in each county compared to their peers in each cluster. The top performing counties in each cluster represented best practices in that group in terms of EMS resources and PI activities. We derived two different peer clusters, one based on UT rates and another based on OT cases.

6. Results

We now present the key findings from our analysis of this data corresponding to each aim.

6.1 Identify and assess current scope and barriers for trauma-specific PI activities

Out of the 1,239 EMS agencies in the state of Ohio, 338 agencies responded (27.3%) to our survey. The majority of the agencies that responded (98.5%, 324) indicated that they either agree or strongly agree that trauma-specific performance improvement (PI) activities improve performance of EMS providers, however, only 63.9% (216) of the agencies indicated they conducted trauma-specific PI activities. Additional resources that were provided by some of the agencies included; post run trauma counseling (27.2%), stress management techniques (19.1%), coping with death of a patient (18.7%), coping with trauma cases (17.2%), life balance (9.5%), critical incident stress debriefing (8.3%) and employee assistance program (8.3%).

For those agencies indicating participation in trauma-specific PI, some of the common activities that were conducted at least once per month include (i) review of completed documentation, including appropriate signatures (~75%), (ii) adherence to the correct protocol/triage plan (~66%), and (iii) reviewing and measuring response time for trauma calls (58.5%). Other activities considered as trauma PI were, PI review of trauma cases, monitoring changes for compliance and effectiveness, and review of PI feedback from the receiving facility or authorizing physicians (see Figure 2).

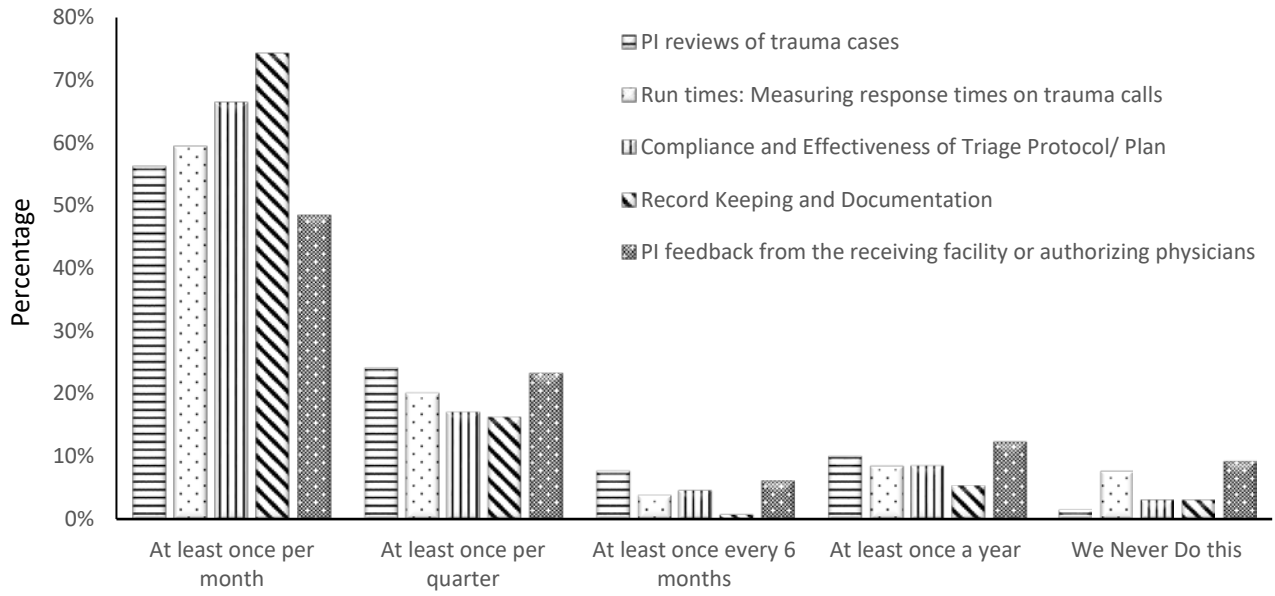


Figure 2: Type and percentage of trauma-PI activities

Among agencies that offer trauma-specific PI activities, primary barriers included; lack of participation or interests from EMS providers (30.2%), lack of financial resources (28.8%), lack of quick hospital feedback and staffing issues (23.4%), unavailability of training centers (10.4%), and a lack of support from the regional or state-level trauma systems (7.2%). Primary barriers for agencies that do not conduct trauma-specific PI, however, included; lack of financial resources (33.2%), lack of participation or interests from EMS providers (25.9%), unavailability of training centers (16.6%), time constraints (13%), and lack of support from the regional or state level trauma systems (11.4%).

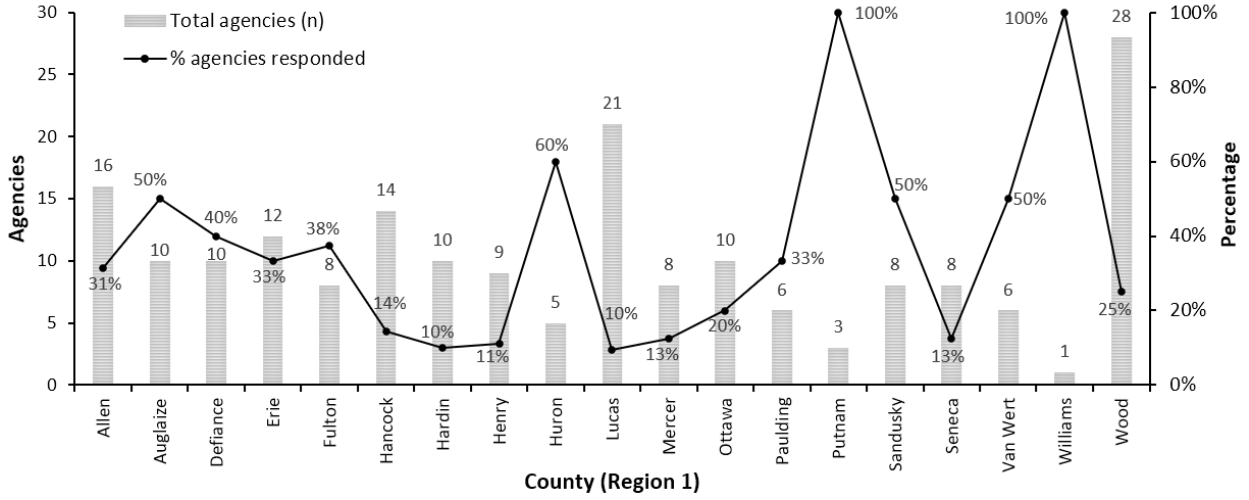
Thematic analysis of narrative responses, as shown in Table 2, suggest that trauma-specific PI activities were helpful in; (i) improving patient care, (ii) enhancing skills and performance of EMS providers, (iii) managing wellbeing of EMS providers and their retention, and (iv) identifying potential agency-level areas for performance improvement. Further, respondents suggested that publishing county and state data to be able to compare an agency's performance to other similarly sized agencies, consolidation and sharing of educational efforts, and synchronization of first responders, trauma centers and physicians along with providing more funding and resources could help improve trauma-specific PI at an EMS level.

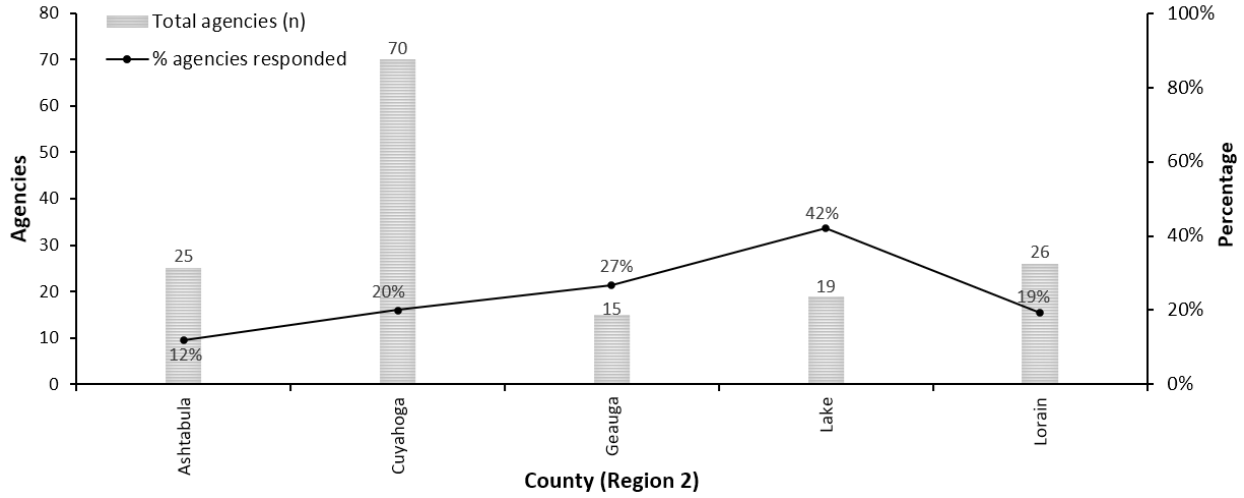
Table 2: Results of thematic analysis and emerging themes

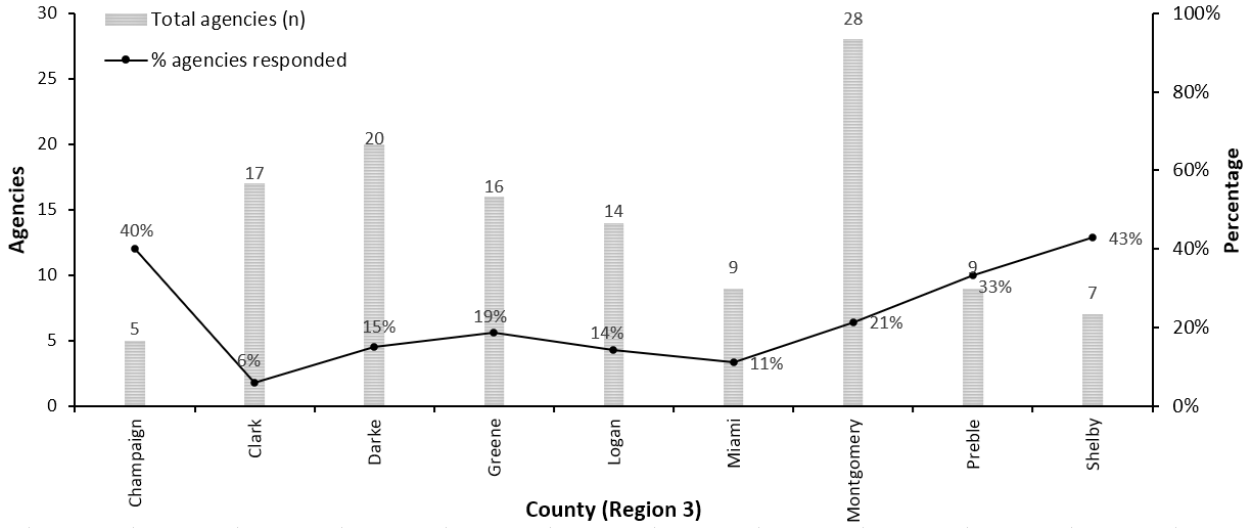
Area	Theme	Description
Positive impact of trauma-PI activities	Improved patient care	Performance improvement program increased patient care and optimized triage, i.e., transport of patients to appropriate facility
	Improved skills and performance of EMS providers	Improved patient assessment and treatment skills, or skills and techniques that are not as frequently used in the field.
	Improved employee wellbeing and retention	Helping EMS employees work through difficult runs or loss of a patient cases improved wellbeing and identified areas for further improvement
	System-level enhancements	Identifying and improving areas of the agency or portions of the agency, decreased on scene time, etc.
Suggestions for Improvement	Increased Funding	Lower volume and rural EMS agencies tended to have less financial availability to fund trauma-specific PI activities.
	Access to County and State EMS Data	EMS agencies need to be able to compare their efforts to that of similar agencies inside their county and throughout the state.
	Consolidation of Efforts	Conducting multi-agency or county wide trauma-specific PI activities standardizes protocols and care, while also saving resources and money.
	Synchronization of Care	Increasing communication between first responders, trauma centers and physicians.

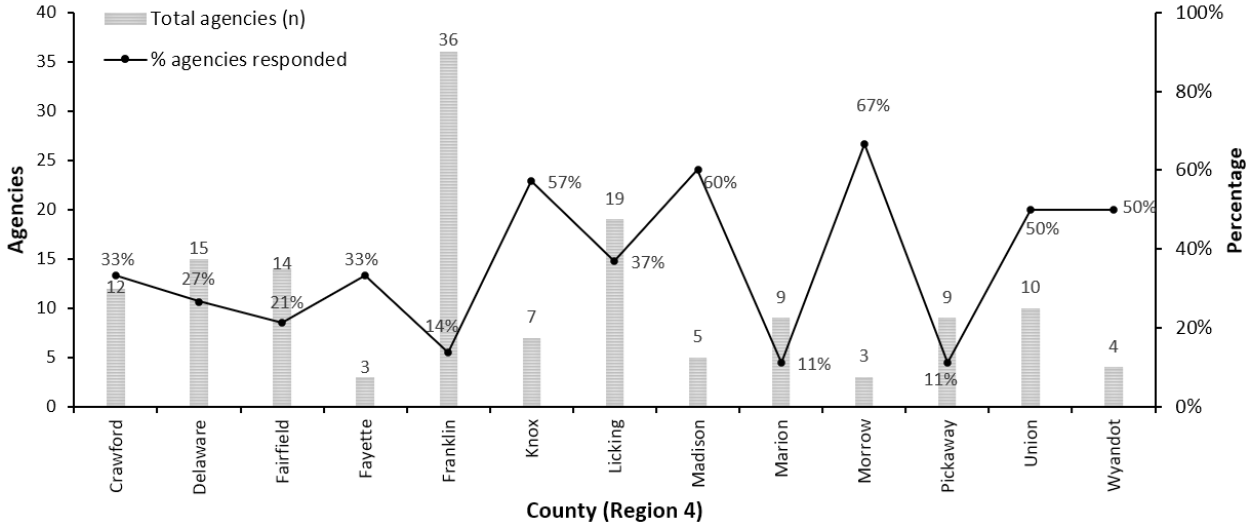
6.2 Peer-Group benchmarking of trauma-specific EMS performance by county

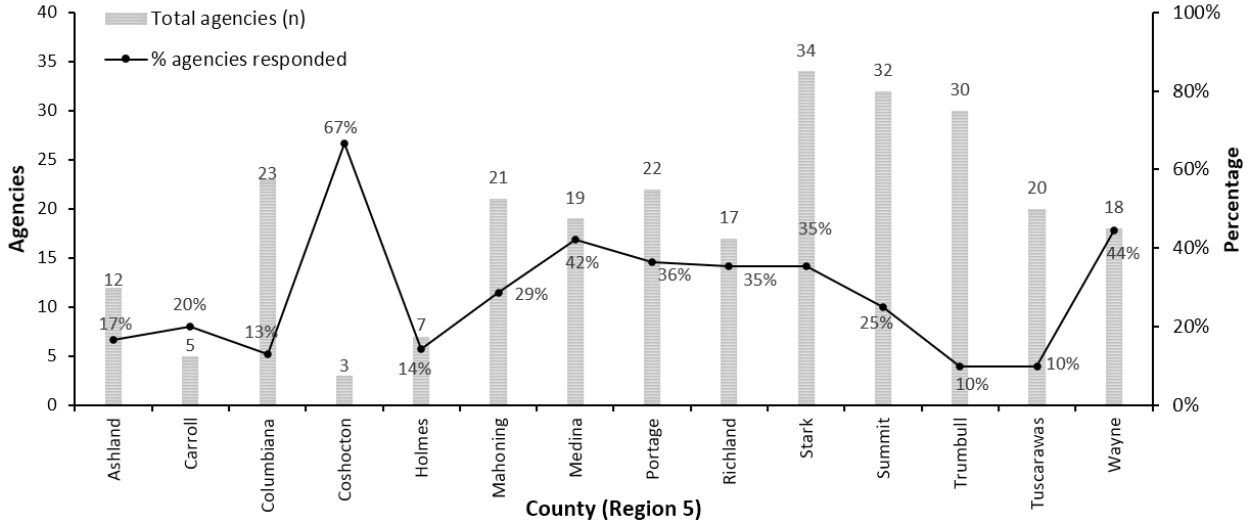
For this aim, we used survey data collected until April 2020 to leave sufficient time for analysis. This included 318 agencies (25.7% response rate) across 87 counties (out of 88 total in the state). These data were appropriately encoded into either categorical or binary form (see Section 5). Two features were removed due to high correlation with other features; Transport Vehicles (Pearson correlation coefficient of 0.75 with EMS Runs and of 0.58 with Paid Workers) and coping with death of patient (Pearson correlation coefficient of 0.78 with Coping with Trauma Case). The distribution of agencies in each county across the 8 regions who responded to the survey are shown in Figure 3 (a-h).

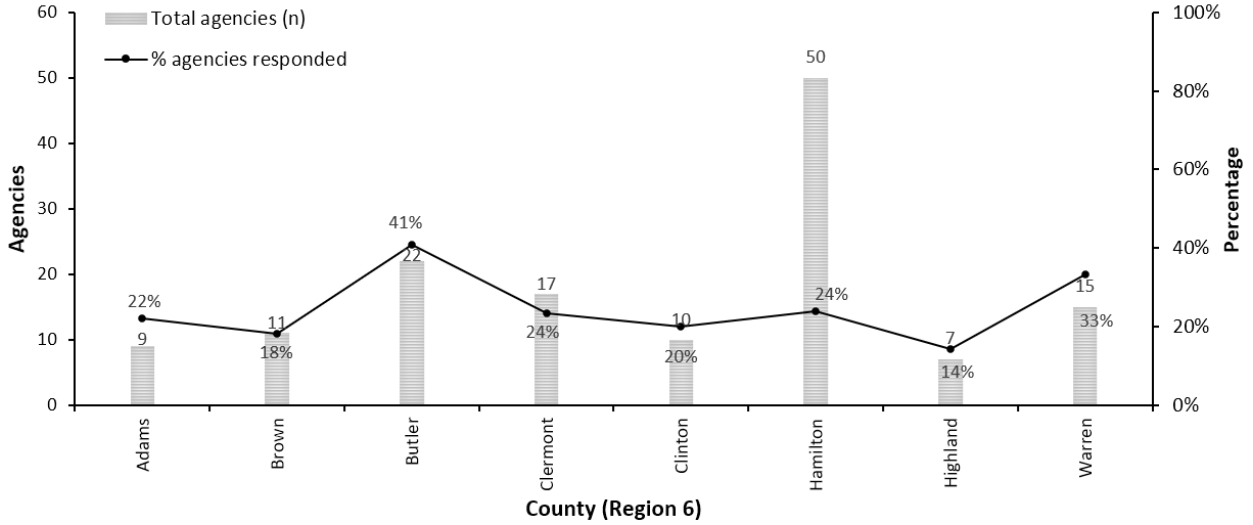

Total agencies (n)
% agencies responded
Agencies
Percentage
County (Region 1)
Allen
Auglaize
Defiance
Erie
Fulton
Hancock
Hardin
Henry
Huron
Lucas
Mercer
Ottawa
Paulding
Putnam
Sandusky
Seneca
Van Wert
Williams
Wood


Total agencies (n)
% agencies responded
Agencies
Percentage
County (Region 2)
Ashtabula
Cuyahoga
Geauga
Lake
Lorain


Total agencies (n)
% agencies responded
Agencies
Percentage
County (Region 3)
Champaign
Clark
Darke
Greene
Logan
Miami
Montgomery
Preble
Shelby


Total agencies (n)
% agencies responded
Agencies
Percentage
Crawford
Delaware
Fairfield
Fayette
Franklin
Knox
Licking
Madison
Marion
Morrow
Pickaway
Union
Wyandot
County (Region 4)


Total agencies (n)
% agencies responded
Agencies
Percentage
Ashland
Carroll
Columbiana
Coshocton
Holmes
Mahoning
Medina
Portage
Richland
Stark
Summit
Trumbull
Tuscarawas
Wayne
County (Region 5)


Total agencies (n)
% agencies responded
Agencies
Percentage
Adams
Brown
Butler
Clermont
Clinton
Hamilton
Highland
Warren
County (Region 6)

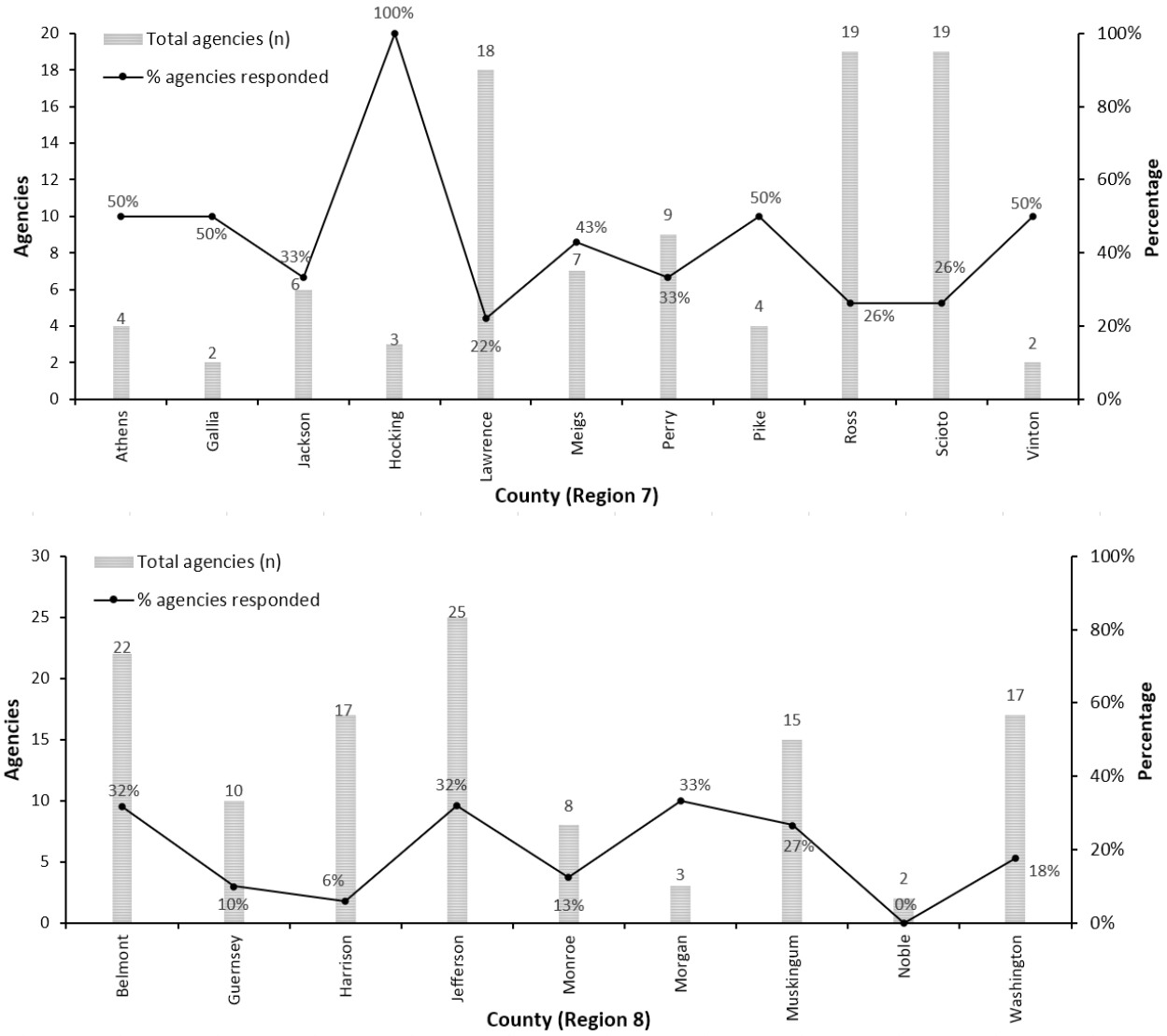


Figure 3: Summary of survey responses by each county in the 8 regions

6.2.1. Identifying and Comparing Clusters

The feature selection approach (based on Random Forest technique) identified Urban/Rural, CSID, LOPI, CWTC, LB, EAP, Volunteer Providers, Paid Workers, Area Covered and EMS Runs as the top 10 factors that determined the cluster formation. Table 3 shows a comparison of the performance of the 3 clustering methods; K-means, K-medoids, and CLARANS. Clearly, both K-medoids and CLARANS resulted in better Silhouette and DB scores; K-means clustering was deemed having insufficient accuracy for further analysis. Further, K-medoids provided consistent and reliable performance compared to CLARANS; counties were always clustered the same way every time K-medoids was run, unlike CLARANS. Therefore, K-medoids was used for clustering and further

analysis.

Table 3: Comparison of clustering algorithms (selected method highlighted in bold)

Clusters	K-Means		K-Medoids		CLARANS	
	# of counties	*Performance*	*# of counties*	*Performance*	*# of counties*	*Performance*
2	(58, 29)	S=0.206 DB=1.78	(48, 39)	S=0.438, DB=1.27	(52, 35)	S=0.481 DB=1.37
3	(25, 27, 35)	S=0.323 DB=1.18	**(35, 29, 23)**	**S=0.547 DB=1.09**	(9, 43, 35)	S=0.503 DB=1.12
4	(35, 21, 8, 23)	S=0.345 DB=1.15	(29, 36, 6, 16)	S=0.391 DB=1.21	(12, 14, 35, 26)	S=0.454 DB=1.38

Figure 4 below illustrates the 3-cluster K-medoids solution; 87 counties were clustered into 35, 29, and 23 counties. Table 4 shows a comparison of the features in each cluster.

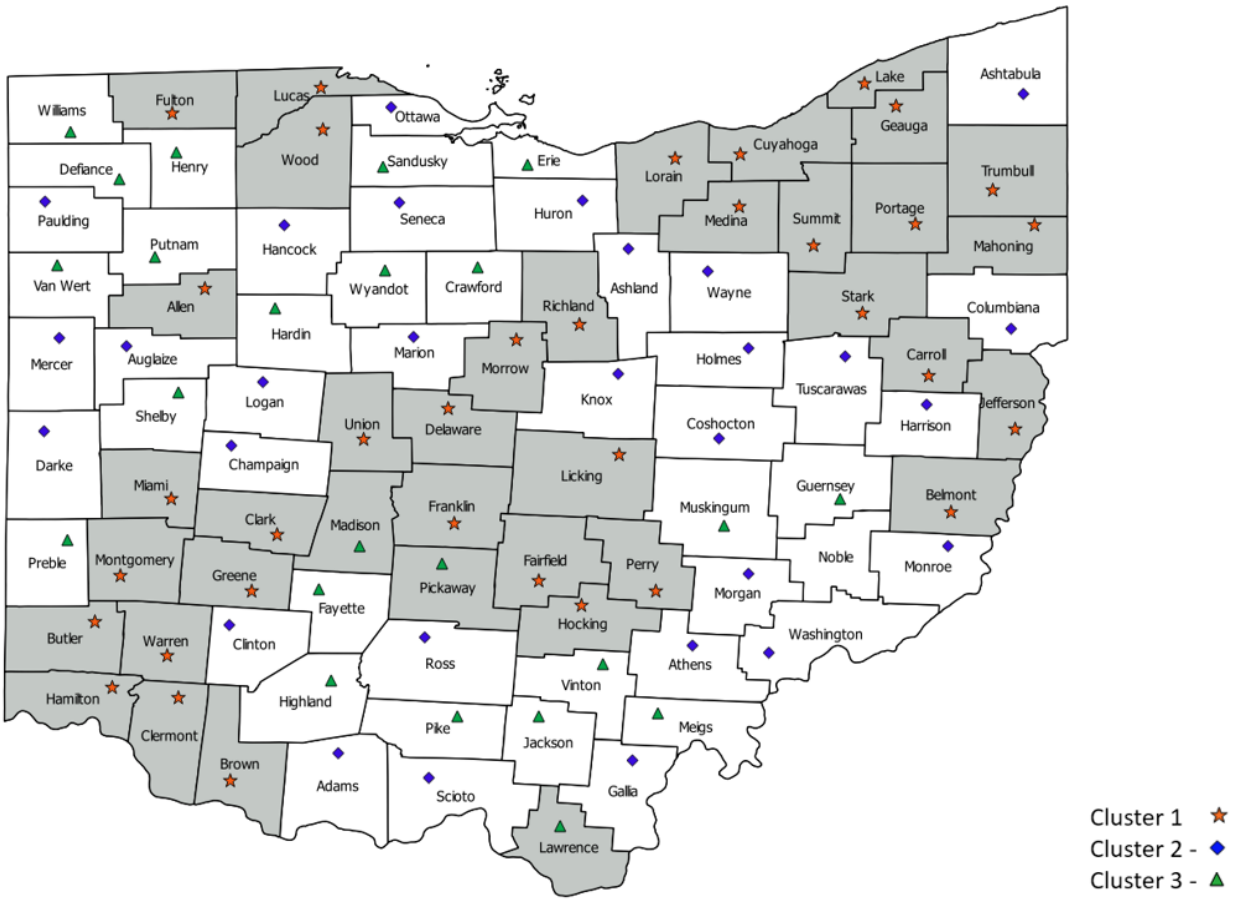


Figure 4: The K-medoids 3-cluster solution of 87 counties; counties with gray background in the map are considered urban counties based on ODPS [14]

Table 4: Comparison of key factors (features) in each cluster

#	No. of County*	Type (U/R)	LOPI	CSID	LB	EAP	CWTC	No. of Volunteers	No. of Paid Workers	Area Covered	No. of EMS Runs
1	35	All U	0.38/0.22 *0.4/0.3*	0.10/0.14 *0/0.2*	0.10/0.15 *0/0.3*	0.06/0.13 *0/0*	0.33/0.25 *0.4/0.5*	217/371 *136/144*	746/1021 *536/661*	1790/2474 *749/1633*	63,177/110,410 *32,500/40,375*
2	29	All R	0.64/0.37 *0.6/0.65*	0.07/0.14 *0/0*	0.19/0.28 *0/0.35*	0.07/0.20 *0/0*	0.40/0.35 *0.5/0.55*	71/86 *40/108.5*	408/441 *210/489.5*	740/1407 *344/694*	31,766/46,225 *16,554/30,628*
3	23	3 U 20 R	0.11/0.19 *0/0.3*	0.65/0.36 *0.75/0.5*	0.58/0.37 *0.6/0.7*	0.55/0.35 *0.5/0.7*	0.73/0.34 *1/0.5*	60/60 *52/84*	223/205 *196/177*	838/1000 *483/666.5*	13,899/14,245 *8,915/14,880*

Note: the values from 'LOPI' to 'No. of EMS Runs' are specified as Mean/SD and *Median/IQR*
Acronyms: U/R = Urban/Rural, LOPI = Lack of Participation or Interest from EMS providers, CSID = Critical Incident Stress Debriefing, LB= Life Balance, EAP = Employee Assistance Program, CWTC = Coping with Trauma Cases

**Specific counties in each cluster are mentioned below*:

- *Cluster 1*: Allen, Belmont, Brown, Butler, Carroll, Clark, Clermont, Cuyahoga, Delaware, Fairfield, Franklin, Fulton, Geauga, Greene, Hamilton, Hocking, Jefferson, Lake, Licking, Lorain, Lucas, Mahoning, Medina, Miami, Montgomery, Morrow, Perry, Portage, Richland, Stark, Summit, Trumbull, Union, Warren, Wood
- *Cluster 2*: Adams, Ashland, Ashtabula, Athens, Auglaize, Champaign, Clinton, Columbiana, Coshocton, Darke, Gallia, Hancock, Harrison, Holmes, Huron, Knox, Logan, Marion, Mercer, Monroe, Morgan, Ottawa, Paulding, Ross, Scioto, Seneca, Tuscarawas, Washington, Wayne
- *Cluster 3*: Crawford, Defiance, Erie, Fayette, Guernsey, Hardin, Henry, Highland, Jackson, Lawrence, Madison, Meigs, Muskingum, Pickaway, Pike, Preble, Putnam, Sandusky, Shelby, Van Wert, Vinton, Wyandot, Williams

Cluster 1 consisted of only Urban counties characterized by EMS agencies with (i) high EMS Runs, (ii) large number of paid workers, (iii) a large number of volunteer providers, (iv) most miles of the area covered, and (v) a minimal number of additional resources offered to employees (e.g., CSID, LB, EAP, and CWTC). Further, for around 38% of EMS agencies belonging to Cluster 1, Lack of Participation or Interest from Employees were regarded as possible barriers to conduct trauma-specific PI activities.

Cluster 2 consisted of only Rural counties characterized by EMS agencies with (i) 2nd highest EMS Runs, (ii) 2nd highest number of paid workers, (iii) 2nd highest number of volunteer providers, (iv) moderate miles of the area covered, and (v) additional resources offered to employees like CSID, LB, EAP and CWTC by these EMS agencies were minimal. For around 65% of EMS agencies belonging to cluster 2, Lack of Participation or Interest from employees were regarded as a possible barrier to conduct trauma-specific PI activities

Cluster 3 consisted of a combination of 20 rural counties and 3 urban counties characterized by EMS agencies with (i) least EMS Runs, (ii) least number of paid workers, (iii) least number of volunteer providers, (iv) least miles of the area covered and (v) additional resources offered to employees like CSID, LB, EAP and CWTC by these EMS agencies were highest among the 3 clusters. For around only 11% of EMS agencies belonging to cluster 3, Lack of Participation or Interest from employees were regarded as a possible barrier to conduct trauma-specific PI activities.

6.2.2. Benchmarking Performance

Given the identified clusters based on the capabilities, volume, and PI activities of counties, we then benchmarked the counties in each cluster using their patient safety (via under-triage cases) and system cost (via over-triage cases) using the 2012 data available from ODPS. For this peer-group benchmarking, we ranked the counties from lowest to highest according to the UT and OT rates (UT=1-sensitivity and OT=1-specificity). Below we mention the high and low performing counties per UT rates in each of the three clusters (Figure 5):

- Cluster 1: There were 11 counties in this cluster (from Allen to Cuyahoga in Figure 4), that experienced several severe trauma cases (defined via ISS>15) and yet achieved ACS recommended UT rate of ≤0.05 [16]. Of these, Stark, Summit, and Cuyahoga had the highest number of ISS>15 cases. Montgomery and Delaware counties had very low UT rate (0.06) as well despite witnessing a higher number of ISS>15 cases. Butler, Portage, Warren, Miami, Clark, Brown, and Perry counties, however, had very high UT rate of >0.5; of which Butler and Clark had the highest number of ISS>15 patients.
- Cluster 2: None of the counties in this cluster had significant number of severely injured trauma

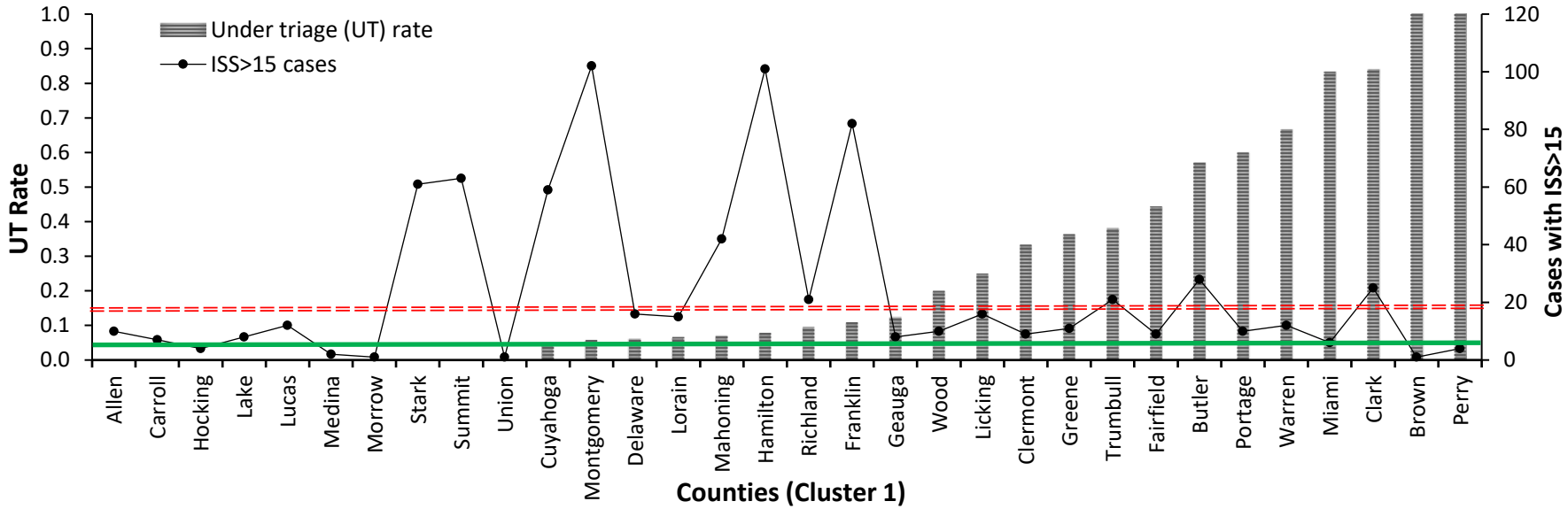
cases (ISS>15) since they all are rural. There were 9 counties in this cluster that achieved UT rate of ≤0.05; Adams, Ashland, Auglaize, Columbiana, Holmes, Morgan, Ottawa, Paulding, and Wayne. The counties with very high UT rates (>0.5) were Huron, Hancock, Clinton, Champaign, Knox, Marion, Seneca, and Washington. This could be due to the lack of access to trauma centers within a reasonable amount of time.

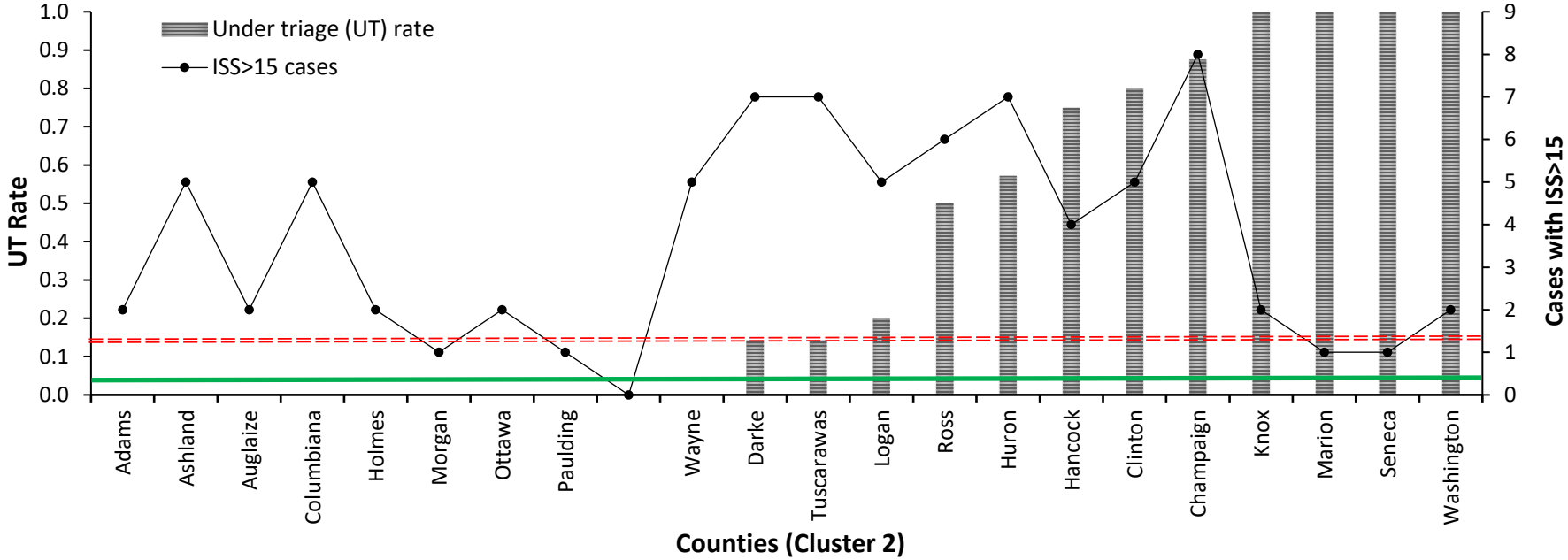
- Cluster 3: Counties in this cluster also did not have many cases of severe trauma. The counties that managed to keep their UT rate ≤0.05 were Fayette, Henry, Madison, Preble, Sandusky, and Williams. Counties with UT rate >0.5 were Muskingum, Erie, Defiance, Guernsey, and Shelby.

Figure 6 shows the high and low performing counties for OT cases in each of the three clusters:

- Cluster 1: In this cluster of all urban counties, several counties were within ACS recommended OT rate of 25% (i.e., 0.25).[2] They were Belmont, Brown, Jefferson, Butler, Morrow, Union, Perry, Clark, Warren, Clermont, Wood, Fairfield, and Lucas. However, some counties such as Summit, Lake, Richland, Allen, Stark, Carroll, and Fulton had OT rate of ≥0.80. Such high OT rates impact resource utilization of the nearby trauma centers and, potentially, their viability.
- Cluster 2: In this cluster of all rural counties, many counties experienced OT rates of <0.25 (Figure 5). However, note that in these rural counties where there were no Level I/II trauma centers available (as of 2012), several counties, such as Columbiana, Ashland, Auglaize, Holmes, Logan, Paulding, and Tuscarawas had OT rate of ≥0.80. Potentially the EMS providers in these counties took ISS≤15 patients to LI/II trauma center in the nearby urban counties. For example, Auglaize county has a hospital (a non-trauma center, NTC), but according to our data, there were 14 cases of OT in Auglaize. We believe that these patients might have been taken to the nearby Allen county that has two LI/II centers. Identifying potential reasons for such on-scene decisions would, however, require further assessments and investigation on trauma triage criteria and agreements between the local EMS and nearby trauma centers in such counties.
- Cluster 3: Similar to counties in Cluster 2, this cluster was comprised of most of the rural counties and a few urbans that do not have any LI/II trauma centers. Counties in this cluster that require further investigation on trauma triage and decision making due to high OT rate (≥0.80) are Putnam, Hardin, Crawford, Van Wert, and Wyandot.

As a side note, counties that had the lowest UT rates experienced very high OT rates. Further, rural counties almost always experienced high UT rate. This could be due to the availability of trauma center in the region. It is, therefore, vital to place trauma centers strategically and optimally for better patient outcomes and optimal utilization of resources.


Under triage (UT) rate
ISS>15 cases
UT Rate
Cases with ISS>15
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
120
100
80
60
40
20
0
Allen
Carroll
Hocking
Lake
Lucas
Medina
Morrow
Stark
Summit
Union
Cuyahoga
Montgomery
Delaware
Lorain
Mahoning
Hamilton
Richland
Franklin
Geauga
Wood
Licking
Clermont
Greene
Trumbull
Fairfield
Butler
Portage
Warren
Miami
Clark
Brown
Perry
Counties (Cluster 1)


Under triage (UT) rate
ISS>15 cases
UT Rate
Cases with ISS>15
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
9
8
7
6
5
4
3
2
1
0
Adams
Ashland
Auglaize
Columbiana
Holmes
Morgan
Ottawa
Paulding
Wayne
Darke
Tuscarawas
Logan
Ross
Huron
Hancock
Clinton
Champaign
Knox
Marion
Seneca
Washington
Counties (Cluster 2)

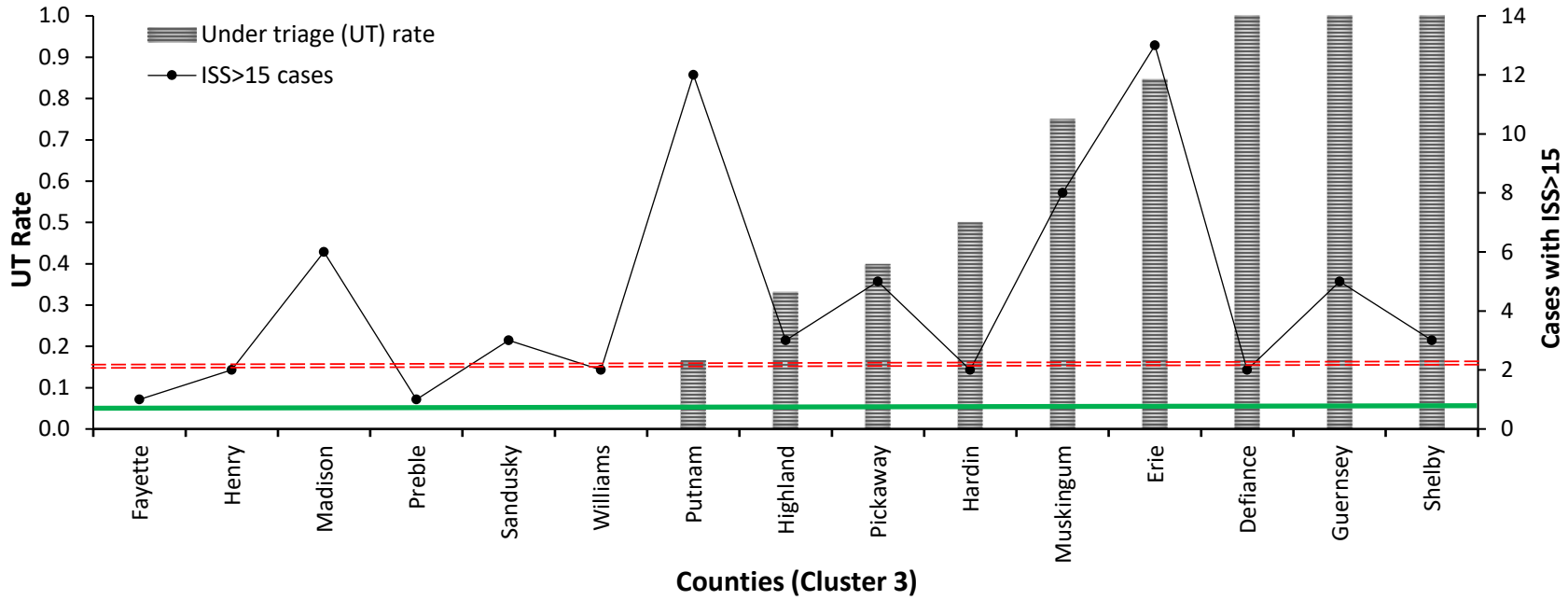
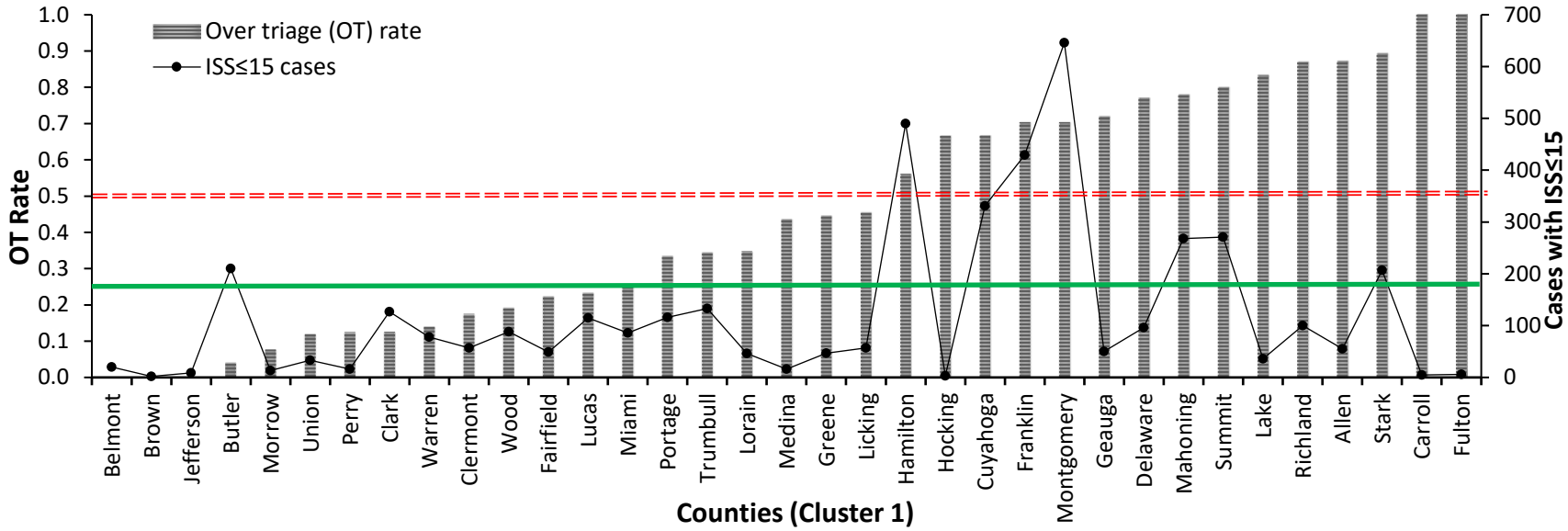
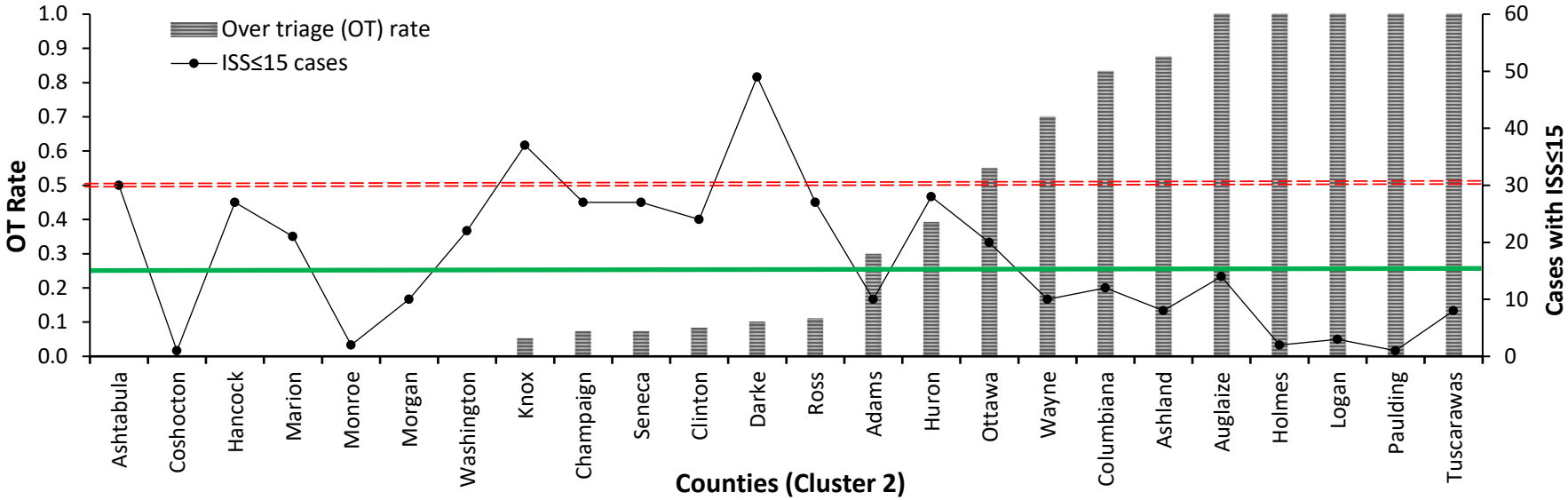


Figure 5: Benchmarking top-performing counties based on county-level UT cases; 'Green line' corresponds to ACS recommendation of UT≤0.05, while 'Red line' refers to 3 times of this recommendation

Note: The following counties were not included in these graphs because of no cases with ISS>15 in that county (6,002 data for 2012)
Cluster 1: Belmont, Fulton, Jefferson
Cluster 2: Ashtabula, Athens, Coshocton, Gallia, Harrison, Mercer, Monroe, Scioto
Cluster 3: Crawford, Jackson, Lawrence, Meigs, Pike, Van Wert, Vinton, Wyandot


Over triage (OT) rate
ISS≤15 cases
OT Rate
Cases with ISS≤15
Counties (Cluster 1)
Belmont
Brown
Jefferson
Butler
Morrow
Union
Perry
Clark
Warren
Clermont
Wood
Fairfield
Lucas
Miami
Portage
Trumbull
Lorain
Medina
Greene
Licking
Hamilton
Hocking
Cuyahoga
Franklin
Montgomery
Geauga
Delaware
Mahoning
Summit
Lake
Richland
Allen
Stark
Carroll
Fulton


Over triage (OT) rate
ISS≤15 cases
OT Rate
Cases with ISS≤15
Counties (Cluster 2)
Ashtabula
Coshocton
Hancock
Marion
Monroe
Morgan
Washington
Knox
Champaign
Seneca
Clinton
Darke
Ross
Adams
Huron
Ottawa
Wayne
Columbiana
Ashland
Auglaize
Holmes
Logan
Paulding
Tuscarawas

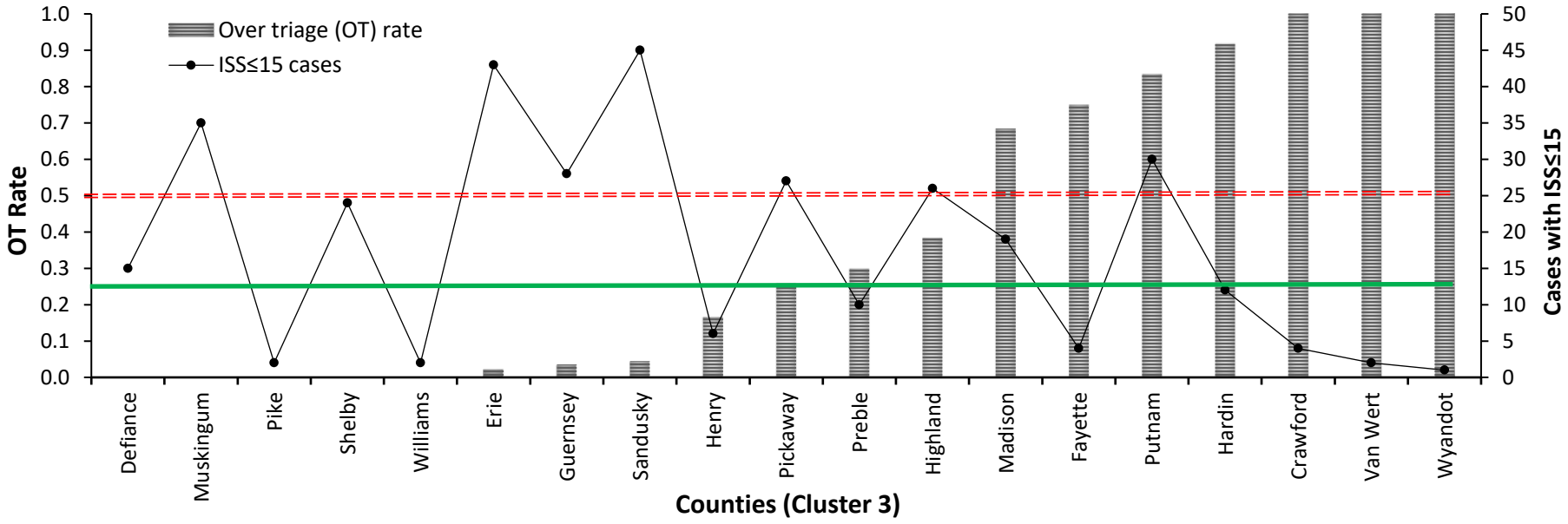


Figure 6: Benchmarking top-performing counties based on county-level OT cases; 'Green line' corresponds to ACS recommendation of OT≤0.25, while 'Red line' corresponds to OT≤0.5

Note: The following counties were not included in these graphs because of no cases with ISS≤15 in that county (6,002 data for 2012)
Cluster 2: Athens, Gallia, Harrison, Mercer, Scioto
Cluster 3: Jackson, Lawrence, Meigs, Vinton

7. Discussion

Our results suggest that there is a significant variability in the execution of trauma-specific PI activities at the EMS level in the state of Ohio, where approximately 36% respondents (i.e., agencies) stated that they do not conduct any trauma-specific PI activities, including assessing appropriate documentation and protocol follow-ups for trauma runs. The lack of appropriate EMS documentation leads to poor outcomes in trauma patients [17].

Our survey of 338 agencies across 87 counties suggested that Primary barriers for conducting trauma-PI activities, however, were, lack of financial resources, lack of interests or participation from EMS providers, lack of available training centers, and lack of support from the regional or state-level trauma systems. Lack of interest or participation from EMS providers could be potentially due to the fact that many EMS providers, especially in rural areas, are volunteers who work on multiple jobs that could create time constraints for them to participate in trauma-PI activities. Other barriers, however, could be overcome by collaboration between agencies and trauma centers.

Further, state-led initiatives in standardizing the trauma-PI activities and structured recommendations could help reduce variability throughout the state. For example, the state of North Carolina developed a fully integrated, statewide EMS data system for quality improvement of EMS service delivery and patient care in the state. This system included a performance improvement toolkit resulting in a significant improvement in the quality of EMS service delivery, patient care, and integrated systems of care [18]. Specifically, their performance improvement toolkit generated a summary report for each EMS agency on the quality and timeliness of their care. Further, the toolkit also enabled individual EMS agencies to benchmark themselves with similar agencies based on EMS service area population and size, and provided specific recommendations to improve their performance. Our thematic analysis results corroborate with these findings; respondents in our survey suggested having access to county and state-level data would help them compare their performance with similar EMS agencies in the state.

Our clustering results showed that type of county (Urban vs Rural), area covered by EMS agencies, EMS Runs, availability of additional resources to employees (stress management, life balance, assistance program, etc.), lack of participation in trauma-PI by EMS providers, and type of employees (volunteer vs paid workers) determined the similarity between counties and clustered them together. Clusters with more rural counties appeared to provide additional resources to their employees, especially in dealing with difficult runs (trauma, patient death, wellbeing, etc.), than urban counties, which seemed counter-intuitive. A more focused survey and interviews of such

agencies may be required to understand the reasons why.

Our benchmarking results also suggested areas for improvement in EMS performance in specific counties within each cluster. We noticed counties that had 2-3 times higher UT or OT rates compared to peer-counties in the same cluster. While some of this may have to do with the dynamics, resource-constrained on-scene EMS decision making process, others may be due to the access to a Level I or II trauma center from the scene (and possible negotiations with such centers). It is critical to identify the reasons for such wide variation in the performance (UT and/or OT) among counties in the same cluster so that appropriate, targeted interventions can be devised and implemented.

8. Conclusions

In summary, we believe that with the increased frequency of trauma, mass shootings, and other large-scale trauma disasters, it is vital for EMS agencies to conduct trauma-PI activities regularly and keep their skills and procedures current. This means that it is essential for state and/or regional system to address any inconsistencies in trauma-PI activities and further elucidate effective measures for the EMS community. Providing access to EMS performance data at county level could also help improve performance. Further, benchmarking of EMS performance compared to their peers is feasible and could provide significant information to improve overall performance of the state trauma system and lead to optimal resource utilization.

9. Dissemination Plan

Part of this work related to Aim 1 was presented as a QuickShot oral presentation at the Academic Surgical Congress (ASC) Annual Meeting (February 2020). A manuscript is currently being finalized based on this work and will be submitted to a journal either in the area of prehospital care or trauma. Another manuscript based on clustering and benchmarking analysis (Aim 2) is being prepared and will be submitted in August 2020 to a medical decision making or similar journal with EMS focus.

10. References

[1] MacKenzie EJ, Rivara FP, Jurkovich GJ et al., A National Evaluation of the Effect of Trauma-Center Care on Mortality. N.Engl.J.Med. 2006; 354 366-78

[2] El Sayed MJ, Measuring quality in emergency medical services: a review of clinical performance indicators. Emerg.Med.Int. 2012; 2012 161630

[3] Joint Commission: Accreditation, Health Care, Certification. https://www.jointcommission.org/; April, 2018

[4] National Hospital Discharge Survey (NHDS), 2010; National Hospital Ambulatory Medical Care Survey (NHAMCS), 2010; National Vital Statistics System (NVSS). All data sources are maintained by the CDC National Center for Health Statistics.

[5] Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Web-based Injury Statistics Query and Reporting System (WISQARS). ; Last Accessed, March 2018 Available at: http://www.cdc.gov.ezproxy.libraries.wright.edu/injury/wisqars

[6] American College of Emergency Physicians, Guidelines for trauma care systems ACEP. Annals of Emergency Medicine 1993; 22 1079-100

[7] Western Virginia Emergency Medical Services Council, EMS and Trauma Care Performance Improvement. http://www.western.vaems.org/performance-improvement; April, 2018

[8] Ohio Department of Public Safety, Developing a Performance Improvement Program. http://www.publicsafety.ohio.gov/links/ems_pim_manual.pdf

[9] Ettorchi-Tardy A, Levif M, Michel P, Benchmarking: A Method for Continuous Quality Improvement in Health. Healthcare Policy 2012; 7 e101-19

[10] American College of Emergency Physicians, Benchmarking in Emergency Medicine. https://www.acep.org/Clinical---Practice-Management/Benchmarking-in-Emergency-Medicine/#sm.00004s6512w2acq8sva1g9hi9dbsw; April, 2018

[11] Myers JB, Slovis CM, Eckstein M et al., Evidence-Based Performance Measures for Emergency Medical Services Systems: A Model for Expanded EMS Benchmarking. Prehospital Emergency Care 2008; 12 141-51

[12] Davis R, Six minutes to live or die. USA TODAY 2003 https://socal-cpr.com/six-minutes-to-live/

[13] Cummins RO, Chamberlain DA, Abramson NS et al., Recommended guidelines for uniform reporting of data from out-of-hospital cardiac arrest: the Utstein Style. A statement for health professionals from a task force of the American Heart Association, the European Resuscitation Council, the Heart and Stroke Foundation of Canada, and the Australian Resuscitation Council. Circulation 1991; 84 960-75

[14] Ohio Department of Public Safety, Division of Emergency Medical Services. 2018 Ohio Trauma Registry Annual Report. 2019 Available at: https://www.ems.ohio.gov/links/2018_Annual_Trauma_Report_FNL.pdf.

[15] Taylor, S. J., and Bogdan, R., Introduction to Qualitative Research Methods: A Guidebook and Resources. 3rd ed. New York: John Wiley and Sons 1998

[16] Rotond MF, Cribari C, Smith SR, Resources for Optimal Care of the Injured Patient. Committee on Trauma, American College of Surgeons. 2014

[17] Laudermilch DJ, Schiff MA, Nathens AB, Rosengart MR, Lack of emergency medical services documentation is associated with poor patient outcomes: a validation of audit filters for prehospital trauma care. J.Am.Coll.Surg. 2010; 210 220-7

[18] Mears GD, Pratt D, Glickman SW et al., The North Carolina EMS Data System: a comprehensive integrated emergency medical services quality improvement program. Prehospital Emergency Care 2010; 14 85-94