Core Disaster Medicine Education (CDME) for Emergency Medicine Residents in the United States

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Abstract

Objectives: Disaster Medicine (DM) education for Emergency Medicine (EM) residents is highly variable due to time constraints, competing priorities, and program expertise. The investigators' aim was to define and prioritize DM core competencies for EM residency programs through consensus opinion of experts and EM professional organization representatives.

Methods: Investigators utilized a modified Delphi methodology to generate a recommended, prioritized core curriculum of 40 DM educational topics for EM residencies.

Results: The DM topics recommended and outlined for inclusion in EM residency training included: patient triage in disasters, surge capacity, introduction to disaster nomenclature, blast injuries, hospital disaster mitigation, preparedness, planning and response, hospital response to chemical mass-casualty incident (MCI), decontamination indications and issues, trauma MCI, disaster exercises and training, biological agents, personal protective equipment, and hospital response to radiation MCI.

Conclusions: This expert-consensus-driven, prioritized ranking of DM topics may serve as the core curriculum for US EM residency programs.

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Background

The increase in disasters that has been occurring world-wide has highlighted that Emergency Medicine (EM) physicians are at the forefront of the management of these crises. Whether one is a new graduate, working solo on a night shift when a chemical exposure occurs at a local industrial site, or a seasoned EM physician working the day of a horrific terrorist event, the ability to immediately recall and apply the core content and principles of Disaster Medicine (DM) is an essential component of EM practice. As passengers expect airline pilots to be prepared for rare, but possible, inflight emergencies, so do communities trust and expect EM physicians to be prepared for these low-frequency, high-acuity events.

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Keywords: curriculum; disaster education; professionalization

Abbreviations:
DM: Disaster Medicine
EM: Emergency Medicine
MCI: mass-casualty incident

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Emergency Medicine program directors have recently indicated disaster-preparedness is one of the most frequently listed components that they want to add to their curricula.[1] However, gaps exist between desire, need, and time.

The Accreditation Council for Graduate Medical Education (ACGME; Chicago, Illinois USA) residency program requirements for EM have minimal recommendations for education in DM, with no clear standard or guidelines for training programs on how to address this broad topic.[2] A 2017 survey of United States EM residency directors indicates that while most training programs include some level of DM education, there is a wide variation in content, methodologies, and dedicated hours.[3] For this reason, many DM leaders have long recommended the development of a common set of core competencies in DM to be required of trainees that will help standardize training and practice in the field. In a study published in 2012, a consensus document addressed the need for basic educational competencies in DM across all fields, and produced a list of core competencies for medical personnel.[4] Despite this growing political and educational interest in DM, there is no indication that these educational goals are currently being met in the field of EM.

The goal of this study was to define and prioritize DM core competencies for EM residency programs through the consensus opinion of experts, including EM professional organization representatives.

Delphi Panel Members and Roles	
Panel Members	**Role**
Paul Biddinger, MD[a]	Content Expert
John Brown, MD	NAEMSP Representative
Jon Burstein, MD[a]	Content Expert
Frederick 'Skip' Burkle, MD[a]	Content Expert
Douglas Char, MD	CORD Representative
Gregory Ciottone, MD[a]	Content Expert
John Hick, MD[a]	Content Expert
Kristi L. Koenig, MD[a]	Content Expert
Charles Little, DO	ACEP Representative
Carl Schultz, MD[a]	Content Expert
Moderators	
Ritu Sarin, MD	SAEM Representative
Eric Goralnick, MD, MS	SAEM Representative

Table 1. Demographics of Expert Panel

Abbreviations: ACEP, American Council of Emergency Physicians; CORD, Council of Emergency Medicine Residency Directors; NAEMSP, National Association of Emergency Medical Services Physicians; SAEM, Society of Academic Emergency Medicine.

[a] Also served as expert reviewer of literature search.

Methods

Investigators utilized a modified, two-round Delphi methodology to generate a recommended core curriculum of DM educational topics for EM residencies. The Delphi method is particularly well-suited for curriculum development, needs assessments, research agendas, and other projects where group consensus is required.[5–7] This process included virtual meetings and offline work with a survey to establish initial priorities for the project, followed by an in-person consensus panel. There was subsequent modification of learning objectives at the in-person meeting based on group consensus, followed by a re-prioritization of these objectives.

The initial steps included a literature review for peer-reviewed articles in PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA) and Hollis (Harvard University; Cambridge, Massachusetts USA) for educational competencies in DM for various health care specialties. The articles were then provided to a core group of seven experts for review and classification of relevance. Expert reviewers were also asked to add additional articles for consideration. The experts were chosen for their established DM expertise in the prehospital, hospital, or policy setting and their history of current or prior practice and engagement with EM training programs in the United States. Given the focus of the study, experts who had not worked with EM training programs in the United States were excluded from participations. Expert panelists participating in this study are listed in Table 1. Articles were scored on their relevancy for review using a binary score of "include" (one point) and "exclude" (zero points) as being pertinent to EM resident education. Those that were scored for inclusion by a majority of the seven reviewers were used to build the competency list (Table 2). The educational content outlined in these articles was compiled and condensed where there were redundant educational objectives outlined by two of the authors. Forty competencies with specific teaching objectives were identified from these articles and shared with the core team of ten independent experts and representatives from the Society of Academic Emergency Medicine (SAEM; Des Plaines, Illinois USA), American Council of Emergency Physicians (ACEP; Irving, Texas USA), Council of Emergency Medicine Residency Directors (CORD; Irving, Texas USA), and the National Association of Emergency Medical Services Physicians (NAEMSP; Overland Park, Kansas USA) via online survey (Survey Monkey; San Mateo, California USA). Participants were asked to prioritize these competencies using a Likert scale of one (not a priority) to five (essential priority) for each competency. They were instructed to rate the competencies specifically based on the applicability and necessity of them being added to an EM residency curriculum, with the goal that participants highly recommend all residencies teach topics with a rating of four out of five, or higher.

Following this online survey, this national expert consensus panel convened to review and confirm rankings of competencies, in addition to clarify wording of objectives for each competency. During this meeting, voting was kept anonymous and investigators utilized controlled opinion feedback. Each category was discussed in full before moving on to the next. The facilitators first displayed the questions for each and then the array of submitted responses. Each participant was invited to advocate vocally for their choice of best answer among the possible choices presented. An anonymous vote was then conducted using Poll Everywhere (San Francisco, California USA), an audience response system that allows participants to answer in anonymity. The results were then shown to the group and participants were again allowed to further advocate and reflect on the results. A final vote was then conducted, and results were displayed.

After the meeting, five teams of two expert reviewers were each assigned eight competencies to edit and review for consistency in wording and inclusion of any critical missing educational components that were discussed at the consensus meeting. There was then an open session for edits and feedback on all 40 newly revised educational categories by the full expert working group. Following this

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Publication Type	Citation
Peer-Reviewed Publication	Collander B, et al. Development of an "All-Hazards" Hospital Disaster Preparedness Training Course Utilizing Multi-Modality Teaching. *Prehosp Disaster Med*. 2008;23(l):63-67. PMID:18491664.
Open Access White Paper	Disaster Medicine Curriculum for Emergency Medicine Residents; ACEP proposal. https://www.acep.org/by-medical-focus/disaster-medicine/.
Open Access White Paper	Emergency Medicine Residency Disaster Curricula Model; ACEP proposal. https://www.acep.org/by-medical-focus/disaster-medicine/. Accessed August 25, 2015.
Peer-Reviewed Publication	Hsu E, et al. Healthcare worker competencies for disaster training. *BMC Med Educ*. 2006;6:19. PMID: 16549004.
Peer-Reviewed Publication	Ingrassia PL. Nationwide Program of Education for Undergraduates in the Field of Disaster Medicine: Development of a Core Curriculum Centered on Blended Learning and Simulation Tools. *Prehosp Disaster Med*. 2014;29(5):508-515. PMID: 25155942.
Peer-Reviewed Publication	Subbarao I, et al. A Consensus Based Educational Framework and Competency Set for the Discipline of Disaster Medicine and Public Health Preparedness. *Disaster Med Public Health Prep*. 2008;2(1):57-68. PMID: 18388659.
Peer-Reviewed Publication	Schultz CH, et al. Development of National Standardized All-Hazard Disaster Core Competencies for Acute Care Physicians, Nurses, and EMS Professionals. *Ann Emerg Med*. 2012;59(3):196-208. PMID: 21982151.
Peer-Reviewed Publication	Waeckerle J, et al. Executive Summary: Developing Objectives, Content, and Competencies for the Training of Emergency Medical Technicians, Emergency Physicians, and Emergency Nurses to Care for Casualties Resulting from Nuclear, Biological, or Chemical (NBC) Incidents. *Ann Emerg Med*. 2001;37(6):587-601. PMID: 11385327.
Peer-Reviewed Publication	Walsh L, et al. Core Competencies for Disaster Medicine and Public Health. *Disaster Med Public Health Prep*. 2012;6(1):44-52. PMID: 22490936.

Table 2. Published Literature Used to Inform Development of Disaster Medicine Competencies

review of the edited 40 competencies, they were shared with the core team of independent experts and representatives to re-prioritize via an online survey, again using a Likert scale of one (not a priority) to five (essential priority) for each competency. For equally ranked items in this second round of review, the expert panel was iteratively queried as to proper scoring using a secure group email. Final rankings of tied items were assigned based on scoring order selected by a majority of participants.

Results

All ten experts completed the prioritization survey and nine of them participated in the consensus conference during the first modified Delphi round. All ten participants engaged in detailed editing and review of the competencies prior to re-evaluation. Nine of the participants engaged in the second prioritization survey, and all ten participated in the final ranking in the second modified Delphi round. Table 3 compares competency rankings after the first round of prioritization, based on teaching objectives found in the literature, to the second re-prioritization round, after expert-panel-generated amendments were made to these teaching objectives.

The 40 competencies were ranked, with the goal that panelists highly recommend all residencies teach topics with a rating of four out of five, or higher. Competencies and associated scoring are listed in Table 4. There were 12 topics with a rating score of four (high priority) or higher, with 28 remaining topics ranked based on priority to address in an EM residency program.

The DM topics recommended for inclusion in EM residency training included: patient triage in disasters, surge capacity, introduction to disaster nomenclature, blast injuries, hospital disaster mitigation, preparedness, planning and response, hospital response to chemical mass-casualty incident (MCI), decontamination indications and issues, trauma MCI, disaster exercises and training, biological agents, personal protective equipment, and hospital response to radiation MCI, and all are listed with detailed teaching objectives in Table 5 (also Appendix 1; available online only). There is a heavy emphasis on key disaster concepts surrounding hospital-based emergency management, chemical-biological-radiological-nuclear explosives (CBRNE) events, and trauma.

Discussion

This study created focused, definable competencies in DM as determined by an expert panel, allowing EM residencies to add the highest value content to their curriculum. While each residency program currently has a variety of resources that allow for differing teaching modalities and depth of exploration of DM topics, the most commonly taught competencies are patient triage and decontamination, both listed as high-priority topics in this review.[3] While there are many education programs and curricula developed for medical practioners,[8–15] a 2016 review of training opportunities indicates that there is not a standard, all-hazards DM training curriculum available for EM physicians who are not seeking to be expert-level practictioners.[16] This prioritized curriculum will allow residencies to focus on the most high-yield topics, ensuring EM residents across all programs are being prepared to the same standards and facilitating their designation as hospital leaders during disasters when the need arises.

The specific topics were developed for EM residencies with the knowledge that some content in these categories is already covered in the EM model,[17] though not always within the construct of DM-based scenarios. Expert panelists noted that many of the highest priority topics are already being taught across EM, including management of blast injuries; chemical, biological, and radiation events; as well as mass-casualty management from trauma. With disasters resulting from multiple etiologies occurring with increasing frequency, including mass shootings and terrorist-based events,[18,19] training to manage a sudden influx of casualties to the hospital from no-notice events is critical.

There are numerous studies addressing novel methods of teaching DM content and improving learners' retention of knowledge, including virtual reality and online gaming systems.[20,21] However, gaps in the literature remain regarding how to select specific topics within DM that are best addressed with these new methods, and how to best use these education strategies in conjunction with other, older techniques. The targeted teaching objectives developed

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Ranking	Delphi Round 1 Ranking	Delphi Round 2 Ranking
1	Hospital Disaster Preparedness, Planning, Response, and Recovery	Patient Triage in Disasters
2	Patient Triage in Disasters	Surge Capacity/Capability
3	Blast Injuries	Introduction to Disaster Medicine/ Nomenclature
4	Decontamination Indications and Issues	Blast Injuries
5	Surge Capacity/Capability	Hospital Disaster Mitigation, Preparedness, Response, and Recovery
6	Disaster Drills and Training	Chemical MCI and Hospital Response
7	Introduction to Disaster Medicine/Nomenclature	Decontamination Indications and Issues
8	Chemical MCI and Hospital Response	Trauma MCI
9	PPE	Disaster Exercises and Training
10	Incident Management Systems (NRF, NIMS, ICS)	Biological Agents
11	Trauma MCI	PPE
12	Hospital Evacuation	Radiation MCI and Hospital Response
13	Biological Agents	Incident Management Systems (NRF, NIMS, ICS)
14	Radiation MCI and Hospital Response	Hospital Evacuation
15	Building Collapse Injuries and Medical Management	Communication
16	Communication	Safety and Security
17	Isolation/Quarantine	Health Consequences of Different Disasters
18	Safety and Security	Building Collapse Injuries and Medical Management
19	Psychological Effects	Personal and Family Preparedness
20	Health Consequences of Different Disasters	Psychological Effects
21	Ethical Issues	Terrorism
22	Prehospital Disaster Management	Ethical Issues
23	Personal and Family Preparedness	Isolation/Quarantine
24	Terrorism	Recognition, Notification, Initiation, and Data Collection
25	Resource Management	Incendiary Event Injuries and Medical Management
26	Patient Identification and Tracking	Legal Issues
27	Contingency, Continuity, and Recovery	Prehospital Disaster Management
28	Legal Issues	Patient Identification and Tracking
29	Special Populations	Populations with Functional and Access Needs
30	Public Health Assessments and Intervention	Resource Management
31	Incendiary Event Injuries and Medical Management	Public Health Assessments and Intervention
32	Tactical Emergency Medicine	Contingency, Continuity, and Recovery
33	Recognition, Notification, Initiation, and Data Collection	Volunteer Management
34	Sheltering	Tactical Emergency Medicine
35	Government Organized and NGO Sponsored Response Teams	Fatality Management
36	Strategic National Stockpile (SNS)	Government Organized and NGO Sponsored Response Teams
37	Volunteer Management	Strategic National Stockpile (SNS)
38	Fatality Management	Sheltering
39	Transportation	Transportation
40	Evidence Preservation	Evidence Preservation

Table 3. Prioritization of Disaster Medicine Competencies after Delphi Rounds
Abbreviations: MCI, mass-casualty incident; NGO, non-governmental organization; PPE, personal protective equipment.

by the expert panel serve as a platform to best benefit physician learners, ultimately leading to improved outcomes for affected patient populations.

While the expert panel focused on prioritizing content, it did not address how to teach the content. Future research involving both this expert panel, as well as a larger working group of residency educators, should build a standard approach to delivering this material, as well as assessments for measuring competency for programs with limited resources in the areas of DM. These findings will be shared via organizational representatives with each professional society for endorsement as investigators progress to the next step of detailed curriculum development.

Limitations

The group of panelists reviewing content did so over approximately 1.5 years. Investigators' initial work occurred in early 2016 with the

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Delphi Round 2 Rank List	Mean Score
Patient Triage in Disasters	4.89
Surge Capacity/Capability	4.67
Introduction to Disaster Medicine/ Nomenclature	4.56
Blast Injuries	4.56
Hospital Disaster Mitigation, Preparedness, Response and Recovery	4.44
Chemical MCI and Hospital Response	4.44
Decontamination Indications and Issues	4.33
Trauma MCI	4.22
Disaster Exercises and Training	4.11
Biological Agents	4.11
PPE	4
Radiation MCI and Hospital Response	4
Incident Management Systems (NRF, NIMS, ICS)	3.67
Hospital Evacuation	3.67
Communication	3.56
Safety and Security	3.56
Health Consequences of Different Disasters	3.44
Building Collapse Injuries and Medical Management	3.44
Personal and Family Preparedness	3.44
Psychological Effects	3.44
Terrorism	3.44
Ethical Issues	3.22
Isolation/Quarantine	3.22
Recognition, Notification, Initiation, and Data Collection	3.11
Incendiary Event Injuries and Medical Management	3
Legal Issues	2.67
Prehospital Disaster Management	2.56
Patient Identification and Tracking	2.56
Populations with Functional and Access Needs	2.44
Resource Management	2.33
Public Health Assessments and Intervention	2.22
Contingency, Continuity, and Recovery	1.89
Volunteer Management	1.89
Tactical Emergency Medicine	1.89
Fatality Management	1.67
Government Organized and NGO Sponsored Response Teams	1.67
Strategic National Stockpile (SNS)	1.56
Sheltering	1.56
Transportation	1.56
Evidence Preservation	1.44

Table 4. Final Ranking of Disaster Medicine Educational Competencies for Emergency Medicine Residencies

Abbreviations: MCI, mass-casualty incident; NGO, non-governmental organization; PPE, personal protective equipment.

first consensus conference in May 2016. Review and editing of content by expert teams continued with an open period of edits by the entire group of experts in early 2017. The last Delphi round took place in the summer of 2017, with final re-rankings and discussion in January of 2018. While this may have created some lack of familiarity with the competencies over time, it allowed the experts to review the content with a fresh perspective each time. Current disaster events may have biased how experts prioritized content between rounds. For example, in the fall of 2017, a group of the experts were deployed as part of response to the hurricane season, while another group was heavily involved in developing a conference focused on urban terrorist events. During this same

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Competency	Mean Score	Detailed Objectives
Patient Triage in Disasters	4.89	• Explain the difference in goals for conventional vs. disaster triage • Demonstrate the ability to sort patients into triage categories that optimize outcomes in scarce resource settings • Understand the modifications in triage necessary in mass gatherings, CBRNE, and infectious disease environments
Surge Capacity/ Capability	4.67	• Explain the difference between medical surge capacity and capability • Identify and define the three basic components of surge capacity (staff, stuff, structure/space) • Name common barriers in the ED and in the hospital to creating medical surge capacity and capabilities • Describe how surge needs are different between a no-notice incident and a slowly evolving incident • Participate in a process (eg, Kaizen, work group, hospital disaster committee) that identifies adequate personnel, supplies, equipment, and space for a patient care surge of 50 or more patients • Describe the surge capabilities and limitations of your local emergency medical care system (EMS and hospital) • Describe the processes used by public health authorities to support and manage medical surge at the local and state levels • Give examples of at least two types of alternate care sites, and list at least three functions and three limitations of an alternate care site • Identify the medical surge capacity assets available in your health care system and community, and identify those which can be deployed in a disaster or public health emergency • Describe the processes your organization may use to expand: o Physical space for patient treatment, and o Personnel, such as callbacks, staff sharing, emergency credentialing, or expansion of scope of practice • Discuss the relationship between surge capacity and capability and the use of crisis standards of care
Introduction to Disaster Medicine/ Nomenclature	4.56	• Define “disaster” and “MCI” • List the four phases of Comprehensive Emergency Management • Understand the “all-hazard” approach to disasters • Explain the concept of “Hazard Vulnerability Analysis” • Define NIMS, NRF, IMS, ICS, EOP, and span of control
Blast Injuries	4.56	• Describe injury patterns that may result from blast-related forces (blast wave barotrauma, penetrating injuries, blunt force injuries, and miscellaneous injuries such as burns and crush syndrome) • Discuss assessment and management of high-order explosive injuries caused by barotrauma to the ears and intestine, with emphasis on blast lung injury, both in the prehospital and ED setting • Identify how the triage and care of blast victims differs from standard triage (immediate and delayed onset injuries)
Hospital Disaster Mitigation, Preparedness, Response and Recovery	4.44	• Understand all hazard preparedness and planning • Be able to explain the difference between internal and external hospital incidents • Understand the goals and role of an Emergency Management Committee • Be able to understand the results of an HVA • Define the three elements that support an HVA: probability, consequence, existing preparedness • Understand the key elements of an Emergency Operations Plan • List the elements of an effective hospital emergency management program • Understand the Hospital Incident Command system and the role of the Hospital Command Center when open • Understand Resource management, Supply and logistics (96 hours requirement, JIT supply issues), and Interagency MOU/MOAs, mutual aid and transfer agreements • Learn about Personnel Training and competencies, staffing patterns, impacts on ability to staff, and integration of medical staff
Chemical MCI and Hospital Response	4.44	• Identify signs, symptoms, and immediate personal safety steps and clinical and response procedures • Provide needed steps for early notification and mobilization of appropriate hospital and local authorities (including key information and immediate actions to minimize damage and protect personnel, the environment, and public safety)
Decontamination Indications and Issues	4.33	• Describe the indications for and benefits of patient decontamination • Define the different levels of chemical PPE • Describe the process and equipment for self-decontamination, and “dry” and “wet” patient decontamination • Define how decontamination for radiation may differ from decontamination for chemical hazards • Describe potential hazards of the decontamination process

Table 5. Essential and High-Priority Disaster Medicine Educational Competencies for Emergency Medicine Residencies *(continued)*

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Competency	Mean Score	Detailed Objectives
Trauma MCI	4.22	• Explain the importance of prospective MCI planning • Understand the characteristics of an MCI vs other forms of disaster • Learn how to initiate a hospital response in a conventional MCI (ED, OR/PACU, ICU, hospital command) • Understand the unique injury patterns of a conventional MCI, including in children • Understand the impact of an MCI on local and regional medical and public health resources • Understand utility of tourniquets in the context of traumatic MCI
Disaster Exercises and Training	4.11	• Explain the importance of training and exercises in disaster preparedness • Describe the differing types of discussion-based exercises (seminars, workshops, tabletops, games) and operations-based exercises (drills, functional/full scale ex) • Explain the relative strengths and weaknesses of tabletop, functional, and full-scale exercises • Understand how to design realistic exercises and how to create after action reports and improvement plans through a "hotwash"
Biological Agents	4.11	• List the common agents of bioterrorism and common means of dissemination • Describe presentations of bioterrorism events compared to endemic diseases • Describe appropriate treatment and the role of prophylaxis and vaccination for anthrax and smallpox • Describe the difference between seasonal and pandemic influenza and implications for the health care system in a pandemic
PPE	4	• Describe the purpose of PPE • Describe how PPE differs for chemical, radiation, and biological hazards • List the appropriate levels of PPE for chemical hazards • List the PPE levels for biological hazards • Describe the appropriate PPE for infectious agents such as TB, smallpox, and viral hemorrhagic fevers • Demonstrate appropriate use of N95 respirators • Describe necessary screening and training for PPE use • Explain the importance of donning and doffing PPE correctly • Demonstrate the appropriate donning, doffing, and disposal of PPE for HAZMAT events • List common limitations, risks, and troubleshooting techniques for PPE
Radiation MCI and Hospital Response	4	• Describe basics of radiation physics • Demonstrate how to prepare your ED for arrival of victims contaminated with radioactive materials • Describe basics of acute radiation syndrome and how to triage based on initial symptoms • Explain the need for operative intervention within 48 hours for patients with higher level of exposure • Describe how emergent medical care interventions may differ in a radiation event from a chemical hazard event • Name nationally available resources to assist with response to a radiation event (Consult experts: Oak Ridge REAC/TS)

Table 5. *(continued).* Essential and High-Priority Disaster Medicine Educational Competencies for Emergency Medicine Residencies

Abbreviations: CBRNE, chemical-biological-radiological-nuclear explosives; ED, emergency department; EMS, Emergency Medical Services; HVA, Hazard Vulnerability Analysis; ICU, intensive care unit; MCI, mass-casualty incident; OR, operating room; PACU, post-anesthesia care unit; PPE, personal protective equipment.

period, others were advising on the Hepatitis A outbreak in California. Ideally, this variety of priorities held by the panelists helped prevent bias in the overall scoring of curriculum components, but this may also potentially have affected the final rank list versus how it might have appeared six months earlier. In addition, the review process and second modified Delphi round was not done in-person due to lack of scheduling feasibility. The expert team members have international reputations as leaders in the field, but they are all based in and primarily practice in the US, as investigators were targeting the US training environment. This did prevent other outside viewpoints which might have influenced the editing of content or prioritization of teaching points.

Conclusion

Table 4 summarizes the prioritized expert ranking of DM topics for inclusion in the US EM residency core curriculum. The content included in the appendix specifies teaching objectives for all 40 teaching points. While the details of standardized assessment and teaching methodology are being developed, EM residency program faculty are encouraged to make use of this content to build upon their own existing DM curricula to help train the next generations of DM leaders and responders.

Supplementary Material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X19004746

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