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Leadership structures in emergency care settings: A study of two trauma centers

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ABSTRACT

Background: Trauma resuscitation involves multidisciplinary teams under surgical leadership in most US trauma centers. Because many trauma centers have also incorporated emergency department (ED) physicians, shared and cross-disciplinary leadership structures often occur. Our study identifies leadership structures and examines the effects of cross-disciplinary leadership on trauma teamwork.

Methods: We conducted an ethnographic study at two US Level-1 trauma centers, one of which is a dedicated pediatric trauma center. We used observation, videotaping and interviews to contextualize and classify leadership structures in trauma resuscitation. Leadership structures were evaluated based on three dimensions of team performance: defined leadership, likelihood of conflict in decision making, and appropriate care.

Findings: We identified five common leadership structures, grouped under two broad leadership categories: solo decision-making and intervening models within intra-disciplinary leadership; intervening, parallel, and collaborative models within cross-disciplinary leadership.

Conclusion: Most important weaknesses of different leadership structures are manifested in inefficient teamwork or inappropriate patient care. These inefficiencies are particularly problematic when leadership is shared between physicians from different disciplines with different levels of experience, which often leads to conflict, reduces teamwork efficiency and lowers the quality of care. We discuss practical implications for technology design.

1. Introduction

Trauma teams are faced with complex problems under time pressure. Teams performing trauma resuscitation form rapidly upon patient arrival and carry out urgent and highly consequential tasks while coping with frequent changes in team composition and dynamics of the environment. Despite the introduction of standard protocols, the diversity of injuries that occur requires a coordinated approach to the evaluation and treatment of each patient. Effective leadership is essential for successful and error-free team performance during trauma resuscitation.

Although there is a large body of research on leadership and team effectiveness, much of it has focused on functions and behaviors of leaders of stable teams, such as those found in production and development teams (e.g., Refs. [1–3]). Leaders

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of stable teams mostly monitor team performance, delegate tasks, and provide guidance, assistance and encouragement. In contrast to stable teams, action teams are highly skilled specialist teams working in a fast-paced context, such as firefighter teams, cockpit crews and military teams. Studies of leadership in action teams have revealed the importance of an effective leader in coordinating task performance in response to unpredictable situations [4–6]. Because action teams often include members with different expertise and levels of experience, leadership may be distributed across several members [7–11]. These studies have offered important insights and provided a foundation for our study on leadership structures in an emergency care setting.

The lack of leadership, ineffective communication, and poor team performance can negatively affect clinical outcomes in several settings, including trauma resuscitation [12–15]. Trauma teams are an example of action teams because their work is highly complex, although structured, and team composition changes frequently to adjust to the rapidly evolving needs of the patient. The presence of an identified and experienced command-physician, such as an attending surgeon or a trauma fellow, enhances team performance and ensures completion of needed resuscitation tasks [15].

Studies of leadership in trauma resuscitation have focused on the adaptation of leaders to changing task demands (e.g., Refs. [16,17]), the impact of leader's location (collocated vs. remote) on team performance (e.g., Ref. [18]), and leadership adaptation to team structure (e.g., Ref. [19]). These studies suggest that different team structures emerge during trauma resuscitation, each in response to the needs of the patient and the team composition. Key gaps in knowledge remain about the nature of leadership structures during trauma resuscitation and their effects on team performance.

Trauma has been referred to as a disease that requires the involvement and leadership of surgeons [20]. Although surgical leadership is common in most US trauma centers, many centers have strong emergency medicine programs, with emergency department (ED) physicians and fellows regularly assuming leadership roles. Our study examines the effects of cross-disciplinary leadership on trauma teamwork.

We conducted an ethnographic study to observe, contextualize and classify leadership structures in trauma resuscitation. The goal of this research was twofold. First, we were interested in the types of leadership structures that occur when leadership roles come from either one (intra-disciplinary leadership) or more disciplines (cross-disciplinary leadership). Because trauma resuscitation involves rapidly changing and multi-disciplinary teams, shared and cross-disciplinary leadership structures are likely to occur. Second, we studied the effects of leadership structure on team performance. We focused on three dimensions of performance: recognition of the designated leader, level of agreement in decision making, and appropriate care delivery. In particular, we examined whether teams recognize their leader when more than one discipline is involved, whether conflict appears because of differing opinions among those sharing the leadership role, and whether leadership structure affects the patient care. Although other dimensions of performance may be affected by leadership (e.g., delay in care delivery), we chose to focus on these three because each is observable and less likely to be confounded by other factors. For example, while prolonged discussion by two leaders could delay care delivery, delays can also be due to missing patient information or an absent specialist. By studying team leadership in the fast-paced, emergency care setting of the trauma bay, we hoped to develop hypotheses about leadership structures and derive implications for technology design to support efficient teamwork and optimal patient care.

2. Trauma resuscitation overview

To treat critically injured patients, trauma team members must work together to achieve the following goals: stabilize the patient by rapidly identifying life-threatening injuries; determine the extent of the injury; develop a plan for definitive surgical management of the patient. A typical team may have 7–15 members or more including an attending surgeon, surgical residents or fellows, nurses, an orthopedic surgeon, an anesthesiologist, a respiratory therapist, a pharmacist and an X-ray technician. Additional specialists such as critical care medicine and neurosurgery may be called as needed.

Roles and responsibilities and chain of command among members of the team may vary between trauma centers. The *team leader*, often a surgical resident or a fellow at many trauma centers, supervises patient care, makes major decisions and delegates work to team members. One nurse is dedicated to the care of the patient and is aided by another nurse who documents the event. The team leader is assisted by a junior surgical resident who performs hands-on evaluation. The individual designated as the team leader may change between residents and attending physicians, depending on the changing condition of the patient and the skill and availability of the individuals involved.

Although a surgeon directs trauma resuscitation in most US trauma centers [20], some centers also involve ED physicians in leadership roles. The leadership structures that result can therefore include leaders from different specialties with different levels of experience. While intended to provide complementary expertise, these leadership structures may result in conflict. Our study examined these issues.

The conduct of the evaluation proceeds in a standard fashion using the Advanced Trauma Life Support (ATLS) protocol, which provides an organized approach to management and treatment of an injured patient [21]. The first step is a rapid evaluation to identify life-threatening injuries (*primary survey*). It is followed by a detailed evaluation for other injuries that need treatment (*secondary survey*). The rapid evaluation may be repeated according to the patient's injury to detect changes in status and to monitor the impact of received treatments. Trauma centers with a high volume of trauma patients and available medical personnel follow a "horizontal resuscitation" approach, by which ATLS tasks are simultaneously performed by individual team members [15]. Leadership roles are crucial in coordinating and integrating team activities to ensure optimal patient outcome when this approach is used.

Although some characteristics of trauma resuscitation are domain-specific, similarities to other time- and safety-critical work settings exist. First, team activities are driven by a set of unpredictable problems, the occurrence of incomplete or

conflicting information, and rapidly changing and evolving observations. Decision making occurs under intense time pressure and involves coordination of trauma team members with variable knowledge and expertise. Second, resuscitation is team oriented. Individual team members perform specialized tasks and the effectiveness of the team depends on both successful task completion by individuals and team coordination. Finally, there is a low margin of error. Errors during resuscitation slow the speed and efficiency of the patient evaluation and may have cascading effects leading to poor patient outcome [22].

3. Methods

To identify common leadership structures during trauma resuscitation, we conducted observational studies at two Level 1 (highest) trauma centers, one treating mainly adult patients and the other treating injured children. By studying teams that are engaged in the same type of activity (trauma resuscitation) following a standardized process (ATLS), but in different settings (adult versus pediatric trauma center), we hoped to identify and characterize leadership structures that may generalize to other emergency care settings.

3.1. Research sites

Both centers provide 24-h emergency and trauma care. Patients treated at these centers have sustained major injuries from motor vehicle accidents, falls, and gunshot or stab wounds. Trauma patients are treated in designated rooms within hospital's emergency department. These rooms contain access to life-saving equipment, patient monitoring and medications. Upon arrival of the patient, the trauma team gathers rapidly around the patient's stretcher, located in the center of the room. To facilitate team coordination, team members are usually positioned around the patient based on their role.

3.1.1. Trauma center one

Our first research site was Robert Wood Johnson University Hospital, a Level-1 trauma center in an urban, teaching hospital in New Brunswick, NJ (from now on referred to as RWJ). This center admits about 1200 trauma patients a year, 17% of which are children. The patients at RWJ are treated in the main resuscitation room (trauma bay). The second trauma bay is available when several injured patients are being treated at the same time. Team structure at this center follows the standard guidelines as described in Section 2. A trauma alert for an incoming trauma patient requires mobilization of the full trauma team.

3.1.2. Trauma center two

Our second research site was Children's National Medical Center, a pediatric Level-1 trauma center located in a pediatric teaching hospital in Washington, DC (from now on referred to as CNMC). The center treats about 1400 injured children each year. Trauma patients at CNMC are treated in one of the two designated rooms within the emergency department, each of which can treat two patients at the same time.

Team structure at CNMC differs slightly from that of RWJ. First, teams are larger and include additional pediatric specialists. The trauma team usually consists of an attending surgeon, a surgical fellow or a fourth-year resident who assumes the team leader role, a bedside physician (usually a junior surgical resident, or a pediatric nurse practitioner) who performs primary and secondary surveys, an anesthesiologist, a respiratory technician, a primary nurse, a medication nurse, a technician, and a nurse recorder. Second, an ED attending physician and fellow are also present. Together with the surgical fellow and attending, they supervise patient care and make decisions. The ED physicians assume responsibility for directing care prior to arrival of surgical team leader.

CNMC has three levels of trauma team activation based on injury acuity: (1) "trauma stat," which requires the presence of a fourth-year surgical resident or a fellow, but not an attending surgeon; (2) "trauma stat attending," which requires the presence of an attending, although presence of a surgical fellow is sufficient; (3) "trauma transfer," which requires members of the core team only, and not attending surgeons or specialists.

3.2. Data collection and analysis

Data at both sites were collected using ethnographic techniques including observation, videotaping and interviews. For each study, we spent over 100 h observing the work of trauma teams. At RWJ, we observed 60 trauma resuscitation events over a two-year period (April 2006–May 2008), 18 of which were videotaped, transcribed and analyzed for communication, team structure and performance, and ATLS protocol compliance. At CNMC, a total of 208 resuscitation events were videotaped between November 2009 and April 2010. Of these, 56 were observed and 121 were reviewed and analyzed for team structure and performance, and ATLS protocol compliance.

To record trauma events, trauma bays at both centers have been equipped with ceiling-mounted cameras and microphones. Wide-angle cameras were mounted above the entrance to provide the entire view of each room. Additional cameras were mounted above each stretcher to capture the activities of team members around the patient.

In addition to observing and videotaping live events, we conducted 16 interviews with team members at both sites, including four attending surgeons, four ED physicians, four fourth-year surgical residents, two junior residents, and four ED nurses. Interviews were semi-structured, lasted 30 min to an hour, and focused on various aspects of trauma teamwork, including resuscitation tasks, information needs and sources, perceptions of leadership, and problems experienced.

Observations, video reviews and interviews yielded detailed field notes and transcripts of events and interview discussions. To identify leadership structures, we used the grounded theory approach [23], a qualitative method by which data are categorized and common themes identified from the data. While analyzing the transcripts and field notes, we focused on instances of decision making and leadership, as well as on communication between the leaders and among the team members. These instances and utterances were coded for their similarity and grouped into themes. The resulting themes were discussed at our research group meetings and

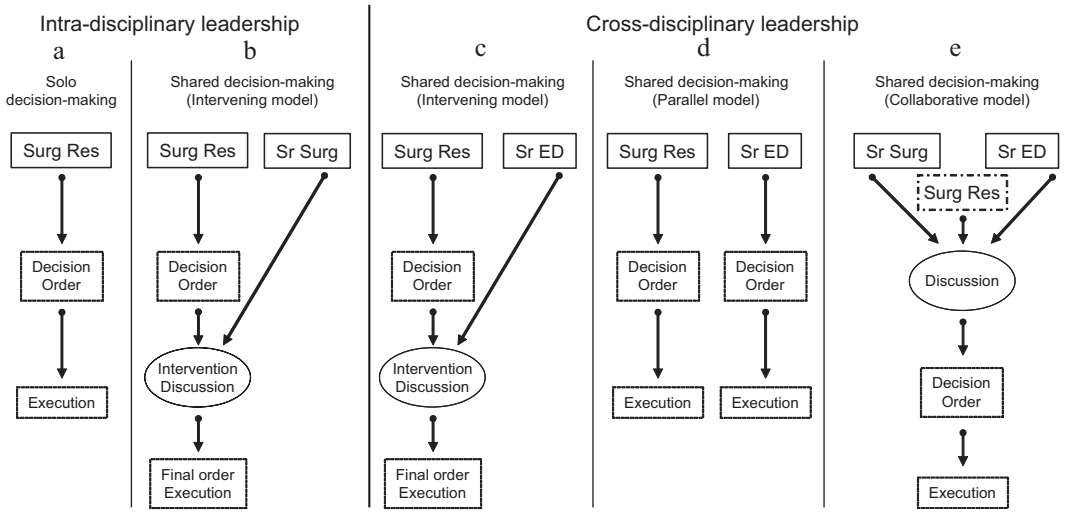

Fig. 1 – Five leadership structures observed during trauma resuscitation. Surg Res is a third- or fourth-year surgical resident with current ATLS certification; Sr Surg is an attending surgeon or a surgical fellow; Sr ED is an attending emergency medicine physician. Both Sr Surg and Sr ED are board-certified or eligible in surgery or emergency medicine with current ATLS certification.

revised until a final set of themes, i.e., leadership structures, was agreed upon. We also examined questions posed among trauma team members to evaluate their level of recognition of the team leader.

3.3. *Participants and ethical approval*

The number of team members involved in this study is difficult to determine because of the dynamic nature of a trauma team. We estimate that observations involved over 200 healthcare providers at each trauma center. The study at RWJ was approved by the hospital's Institutional Review Board as a non-exempt protocol and required informed consent of all participants in advance. The study at CNMC was approved by the hospital's Institutional Review Board as an exempt protocol.

4. Findings

We identified five leadership structures occurring during trauma resuscitation (Fig. 1). When only surgeons were responsible for managing trauma resuscitation (intra-disciplinary leadership), two leadership structures emerged: *solo decision-making* and *shared decision-making—intervening model*. When leadership was shared between general surgery and ED physicians (cross-disciplinary leadership), three leadership structures emerged: *shared decision-making—intervening model*, *shared decision-making—parallel model*, and *shared decision-making—collaborative model*.

4.1. *Intra-disciplinary leadership: solo decision-making*

At RWJ, the leadership role was assigned to an ATLS-certified, third- or fourth-year surgical resident (Surg Res in Fig. 1). A board-certified attending surgeon or a fellow with current ATLS certification (Sr Surg in Fig. 1) was present most of the time. However, we observed the attending surgeon being delayed by other duties for several minutes in one third of events. Also, when more than one injured patient was treated, the attending surgeon often switched between different rooms. In both situations, the surgical resident acted as the solo leader without attending surgeon's supervision. We call this leadership model *solo-decision making*, Fig. 1(a).

To make a decision, the team leader relied on other roles to acquire, retain and validate information needed for decision making. Critical patient information was acquired using tasks such as observation, physical assessment, and instrument reading. For example, a junior resident may observe whether or not the patient is conscious, or assess the patient's breath sounds and pulses. A technician may connect the patient to the vital signs monitor and read out the vital sign values. Patient information collected by individual team members was communicated to the team leader, who then made a decision about the treatment or the next evaluation step. The following vignette describes a typical case of solo decision-making that we observed at RWJ:

> *After hearing initial, pre-hospital report about patient injuries, the team leader assessed the patient' airway and moved onto examining breath sounds. Junior resident examined the pulses and reported,* "He's got distal pulses!" *Shortly after, the leader reported,* "I've got clear breath sounds!" *While palpating the patient's abdomen, the leader inquired,* "We got a pulse on him?" *and the technician responded,* "Yes." *The leader then performed a quick assessment of the visible injuries and reported,* "Contusion on neck, left side! Left leg deformity!" *The leader glanced at the monitor and reported,* "84 pulse rate!" *Shortly after, the technician reported vitals,* "BP 167 over 77, heart rate 58." *The leader then asked junior resident,* "He's got good distal pulses?" *Junior palpated the patient's feet and confirmed,* "Yes, he's got them!" *The leader moved onto neurological exam and reported,* "Pupils dilated on the left, 4, on the right 2." *He*

then inquired, "Do we have x-ray here?" *As the technician and nurse were getting ready to administer fluid, the leader said,* "Get x-ray ready, we'll roll him after this!"

Our data showed that solo leadership facilitated information exchange and teamwork because of a clear understanding of who was the team leader. This observation is consistent with findings from other studies about the importance of an identified physician leader [12,15]. The analysis of questions in 18 events at RWJ showed that 19% (137/714) of all questions by the team members were directed to the leader. Team members turned to the leader when they needed information about the evaluation findings (e.g., "*Is she responsive?*"), equipment (e.g., "*Do we have a cuff on her?*"), medications (e.g., "*What are we going to do for keeping him sedated?*"), treatments (e.g., "*Do you want to give him oxygen?*"), and vital signs (e.g., "*Do you need a blood pressure?*").

While there are benefits of having a single decision maker, solo decision-making in trauma resuscitation may have negative effects on patient care, such as increased likelihood of performing unnecessary procedures or missed important evaluation or management steps. Although surgical residents at RWJ had considerable experience in treating severely injured patients, their approach to patient care was often more cautious. This approach sometimes resulted in additional treatments or procedures that would not have been recommended by a more experienced physician. The following vignette shows an event in which the attending physician arrived late and the leader recommended insertion of a chest tube without sufficient evidence:

An adult male patient with four stab wounds was brought to the trauma center. Emergency services paramedic reported clear lung sounds and normal vital signs in the field. The team leader then listened to the patient's breath sounds but did not report his findings. Junior resident examined the patient's pulses and reported, "Got femoral pulses! Got distal pulses!" *The leader palpated the patient's wrists to assess radial pulse. Shortly thereafter, the technician reported blood pressure,* "149 over 72!" *The team leader quickly assessed the stab wounds and then ordered,* "We'll give him a chest tube!"

In a post-event video review and discussion of this case with an experienced trauma surgeon, we learned that the leader did not adequately assess the patient's airway and breath sounds, and evaluate oxygen saturation before making his recommendation.

4.2. *Intra-disciplinary leadership: shared decision-making: intervening model*

A common practice at teaching trauma centers, such as RWJ, is that residents rely on on-the-job learning while receiving real-time feedback from attending surgeons. In most cases we observed at RWJ, the attending surgeon was present. The surgical resident usually managed the resuscitation process, and the attending was in a teaching mode, allowing the team leader to perform their role under supervision, intervening as needed to provide guidance in the evaluation and management. Because interventions were usually followed by a brief discussion, e.g., explaining why an intervention was necessary or why an initial decision was not appropriate, we call this leadership structure *shared decision-making—intervening model* (Fig. 1(b)). The following statement by an attending surgeon illustrates the nature of this leadership structure:

"When I walk in [to the trauma bay], I watch what the team leader is doing. I may look at the vital signs monitor and stand back and watch what the team leader is doing and listen to information that he provides. Usually I don't comment if everything is proceeding normally, I just allow process to occur. The only time I intervene is if there is some task that other people wouldn't able to do. I am just another set of hands, getting an overview of what's going on. I give feedback to the team leader if there is some deviation from the plan." [Attending#1]

At RWJ, we observed the work of seven attending physicians. Although each had a different working style, they all used the same approach to participating in resuscitation: they would arrive to the trauma bay, inquire about the patient status directly from the leader or the nurse recorder, observe the evaluation process, and intervene if necessary. Interventions included modifying orders for fluid or medication therapies, adding or preventing procedures or tests, reminding the leader of needed steps in evaluation and management, and assisting with complex procedures. The following vignette describes an episode in which the attending modified the leader's decision about a medication therapy:

The team leader ordered a bolus of an anesthetic drug called Diprivan, to keep the patient sedated. As the nurse was getting ready to administer the drug, the attending surgeon intervened, "Don't give him a bolus." *The leader looked at the attending and inquired,* "No?" *The attending responded,* "No. I don't know what his blood pressure is and that bolus will drop his pressure. If you want to give him something, give him 2 of Versed."

Our previous study of decision-making activities showed that interventions by the attending surgeon occurred rarely [24]. Our current observations showed that these interventions did not negatively affect teamwork and information exchange. Despite order modifications and other interventions, the team continued to have a clear understanding of who was leading the team. This continued recognition of a designated leader manifested through team members' questions directed to the leader as opposed to the attending. Our analysis of questions showed that team members' inquiries directed to the attending accounted for only 6% (43/714) of questions in 18 resuscitation events. Most of the questions related to modified medication or fluid orders (e.g., "*I have 1 gram of Ancef here, is that what you want?*"). Among these questions, almost one third came from the team leader suggesting that attending surgeons' interventions were often invited rather than imposed. The following example illustrates the interchange between the team leader and an attending about the preferred medication therapy:

Upon completing initial patient evaluation, the team leader briefed the attending, "Breath sounds bilaterally, trachea midline. I don't feel any clavicle fractures, right now breath sounds equal bilaterally." *The attending first asked for a summary of the injury mechanism and then continued,* "My

Table 1 – Distribution of leadership structures across 208 events observed/reviewed at CNMC.

Leadership structures at CNMC ($n = 208$)				
Surg resident/fellow	Surg resident and ED physician	Sr surgeon and ED physician	Surg resident, ED physician & Sr surgeon	Other
3 (2%)	92 (44%)	84 (40%)	17 (8%)	12 (6%)

guess is that he ah... he'll be okay, I guess he had a tension pneumothorax." *The leader acknowledged, continued the assessment, and reported,* "His belly is soft, he's not breathing against the ventilator." *The attending advised,* "Well, once we get all our exams done, we can wake him up." *The leader then inquired,* "What do you... do you have any preferences to keep him intubated?"

The intervening leadership model rarely resulted in conflict due to differing opinions between the leaders and attending physicians. Two explanations may account for this observation. First, attending surgeons and surgical residents come from the same discipline, have undergone the same training, are using the same body of knowledge, and are approaching patient care from the same perspective. Second, differential and hierarchical structure of the team may make members in subordinate roles (e.g., resident is subordinate to attending) reluctant to express their concerns. Similar explanations have been found in other domains with hierarchically organized teams [25,26].

Finally, our observations showed that attending surgeon's interventions reduced the incidence of unnecessary procedures and missed steps. The presence of another individual in a leadership role, such as the attending surgeon, improved the team leader's performance by providing advice and serving as a consultant for more complex decisions.

4.3. *Cross-disciplinary leadership: shared decision-making: intervening model*

During our study at CNMC, we observed only three cases with surgical residents or fellows working as solo decision makers. Because this trauma center requires the presence of an ED physician or a fellow in every resuscitation, events we observed involved physician leaders from both disciplines, i.e., general surgery and emergency medicine. Our observations revealed three types of shared leadership structures: *intervening model*, *parallel model* and *collaborative model* (Fig. 1(c) and (e)). The distribution of leadership structures and roles observed at CNMC is shown in Table 1.

Similar to the intervening model observed within intra-disciplinary leadership at RWJ, the intervening model at CNMC involved a fourth-year surgical resident (Surg Res in Fig. 1) and a senior physician, with the senior physician monitoring and intervening to modify decision making or specific orders. In contrast to RWJ, the intervening model at CNMC differed because of the different relationship between the supervisory physician and team leader, with each being in different discipline without a formalized hierarchical relationship. Because ED physicians at CNMC were immediately available when patients arrived, they often assumed an advisory role for the team leader before the attending surgeon arrived or when they were unavailable. This leadership structure was observed in 44% of the events we reviewed for this study.

Managing a critically injured child requires modification of some ATLS components for child anatomy and physiology. For example, fluid and medications need to be dosed according to the patient's weight and the neurological examination needs to be adjusted for the developmental stage. Because of their broader experience treating children, the ED physicians at CNMC provided complementary expertise for pediatric-specific management of the patient. In the following vignette, the ED physician provided guidance to the surgical resident in the calculation of the Glasgow Coma Score (GCS), a neurological scale for assessing the patient's consciousness (GCS of 8 or lower indicates the need for endotracheal intubation):

Sr ED (talks to residents): "Do you guys have a GCS?"

Surgical resident (talks to team): "GCS, ah... Eyes, uh, two. Verbal is four. And motor is gonna be one. She's not moving."

Sr ED (to Surgical resident): You're giving her a GCS of less than eight?

... [*silence*]

Sr ED (talks to team): "I cannot give her a GCS of seven. So I'd give, just saying from here, I'd give eyes three, motor response we'll give a five. And verbal we'll give a four. Three, four, five."

We also observed surgical team leaders asking ED physicians for advice about certain procedures. In the following example, the leader consulted the ED physician about the preferred imaging tests ("trauma series" refers to general X-ray protocols):

Sr ED (to Surgical team leader): "Are you just gonna get a trauma series?"

Surgical team leader (to Sr ED): "Pelvis isn't tender, I'm not inclined to do pelvis. I'll get a chest x-ray though."

Nurse recorder (to Surgical team leader): "And I take it you want c-spine too?"

Surgical team leader (to Nurse recorder): "Uh, yeah."

Surgical team leader (turns to Sr ED, asks): "Are you ok with that?"

Sr ED (shrugs shoulders)

Interviews with surgical residents and ED physicians revealed both positive and negative aspects of this cross-disciplinary intervening model. The team leaders are fourth-year surgical residents who have had experience treating injured adults at other high volume trauma centers. In contrast, ED physicians at CNMC are experienced in pediatric

emergency care and have knowledge of the overall system and functioning of the pediatric emergency department. Shared leadership often strengthened overall leadership by providing complementary expertise. The following statement by a surgical resident illustrates the benefits of shared leadership:

> "*From a surgical-resident standpoint, it's helpful to co-manage the resuscitation with an ED attending, especially from pediatric standpoint... their experience is very valuable because, unlike fellows and attending physicians here, I am not a pediatric surgeon, so having somebody who has expertise in pediatrics there, is, I think, beneficial.... It's not essential but it's definitely beneficial.*" [Resident#4]

Similar view was expressed by a senior ED physician, as follows:

> "*... I think we are of a big help in helping [surgical residents] with the system, and that system can include facilitating the relationship for the nurses in the emergency department to when they say, 'well this guy needs a vascular surgeon I don't even know who to call' [...] I think the collegiality of I have my way of knowing how to move the system along, they have their way of knowing stuff, I think that works actually well.*" [EDPhysician#1]

Although beneficial, shared leadership between a surgical resident and a senior ED physician sometimes led to conflict because of different disciplines and less structured hierarchy. Discussions associated with conflict mostly related to imaging and lab decisions, as shown in this excerpt from an interview:

> "*[Surgical residents] do very reflexive ATLS approaches to scanning children [...] so I think we are much more aggressive here about intervening, so this does create unnecessary discussion. So I think this is where the conflict happens, if junior residents are like 'let's pan-scan the child' and you are like 'that's not OK.'*" [EDPhysician#4]

Disagreements about invasive interventions, such as intubation, were rare because both sides believed that strong evidence is needed before deciding on such procedures.

Another problem that emerged as a result of shared leadership between a surgical resident and a senior ED physician is that of a clear leadership designation. Because orders originated from both leadership roles, members of the team were often confused about their designated leader. This confusion was particularly evident among nurses on the team. While the surgical team leader issued most orders, the ED physicians sometimes modified or cancelled their orders. Nurses on the trauma team tended to clarify with ED physicians rather than with surgical residents, which is not surprising because the nurses more commonly work with ED physicians. Contradictory orders caused frustration among the nurses:

> "*Orders come from everywhere and it's your job to kind of say 'I need you to agree and tell me one thing' because it doesn't always happen. [...] It's not clear all the time who do we listen to. During traumas, the surgical team leader is the one in charge but when you have a nurse practitioner and a resident and a surgical team leader and an ED attending in there, who are all kind of discussing different things, they need to work together more to have one directed place where the orders are coming from.*" [Nurse#3]

To mitigate the problem of identifying the team leader, CNMC instituted the practice of wearing role-tags (self-adhesive paper tags indicating members' roles). Upon gathering in the trauma bay, members introduced each other by name and their role in the forthcoming trauma resuscitation. Although role-tags and introductions improved communication and team interaction when used, challenge remains in determining how to sustain these practices when patients arrive shortly after announcement and teams have limited time to prepare.

4.4. *Cross-disciplinary leadership: shared decision-making: parallel model*

Parallel model involves the same leadership configuration as the intervening model, i.e., a fourth-year surgical resident and an ED attending (Fig. 1(d)). The main difference between the two models is that leadership roles rarely interact. In a typical parallel model situation, both leadership roles supervise patient care independently and provide a separate set of orders. The following example illustrates parallel streams of orders issued by the team leader and ED attending:

> *The team leader started assessing the patient and the primary nurse was checking IV access on the patient's left arm. Seeing the nurse working around the IV, ED physician ordered,* "We need blood work too off these lines!" *The leader asked,* "What is our blood pressure?" *and continued with the examination. Shortly after, the technician read out the first blood pressure values,* "57 over 30." *While the primary nurse was still working on the IV and the leader was reporting his findings, ED physician took the manual blood pressure equipment and ordered to nursing part of the team,* "I need somebody to take the manual blood pressure... *[*primary nurse's name*]?. [*medication nurse's name*]?"* *The team leader followed,* "When we enable the line, we are going to roll him to check his back."

In a discussion following this event, a nurse expressed dissatisfaction with leadership:

> "*There was no direction, there was no clear communication, somebody was like 'start the 3%' and I was like 'o-k-a-y, but I need to make sure the line is correct' ... I believe I was ordered by an ED physician to start a new line... I know that [ED physician's name] was trying to get the leadership because she saw there was a lack of thereof... the problem was that we had weak surgical leadership. I felt like I was receiving guidance from my ED physician, but there has to be communication back and forth between ED physicians and surgery.*" [Nurse#1]

Among the leadership structures that we have identified (Fig. 1), the parallel model had the most negative effects on team performance. First, it negatively affected teamwork because it led to a schism between leadership roles, resulting in confusion about a designated trauma leader and impairing communication among the team members. Because orders were given separately, team members had problems following and sometimes even understanding the orders, as well as determining which orders to carry out. Confusion was especially noticed with medication orders, as indicated by Nurse #4:

"*The biggest thing is with medications. There have been times when I was in there and I'd be 'give it' or 'don't give it' as they are trying to figure out what they want to do. When 3% saline first came out, you'd have the argument, give 3% saline or give Mannitol, so we'd go back and forth on that.*"

Second, the lack of interaction between the leadership roles increased the chances for unnecessary procedures. The parallel leadership appeared to be an avoidance reaction on the part of the two lead physicians. Sometimes, the team leader and the ED attending chose to avoid conflict rather than trying to interact and reach an agreeable solution. Consider the following excerpt from an interview with EDPhysician#1:

"*. . . if there are things that are just differences of opinion and I don't think it's going to hurt the patient, I usually would push for a more cautious approach, in other words, if they want to give an extra x-ray and I don't want to give an extra x-ray, I am not going to stop the x-ray from happening if that is a more cautious approach.*"

4.5. *Cross-disciplinary leadership: shared decision-making: collaborative model*

In collaborative leadership model, surgical resident was usually accompanied by an attending surgeon or fellow (Fig. 1(e)). This leadership structure was observed in 8% of events reviewed for this study. As we learned from the interviews, ED physicians were comfortable with this team configuration because there was a senior surgeon present. Interaction between the two senior physicians was characterized by higher level of mutual trust and frequent conversations. We consider this model the most collaborative leadership structure we have observed, as illustrated in this example:

Team leader (talks to Sr ED): "Let's discuss our strategy for a second."

Sr ED (talks to Team leader): "We've done three doses of Epi, one through the ET tube, two IV. Uh, we decompressed the right side. We haven't given him blood yet. And we are ten minutes into the resuscitation."

Team leader (talks to Sr ED): "Plus probably 15 minutes from the injury. He never had any documented vital signs, at least not since he arrived here. Thoracotomy? I would say no. It's been too long and we didn't have documented vital signs."

Collaborative leadership model had positive effects on the overall team performance. For example, we observed resuscitation events ending with positive feelings shared between the leaders and among the team members. The following discussion between a senior surgeon and an ED physician at the end of an event shows this positive attitude:

Attending surgeon (talks to team): "Alright, thank you everybody."

Sr ED (talks to Attending surgeon): "Thanks, [first name], do appreciate your help."

[Attending surgeon and Sr ED shake hands]

Sr ED (talks to Attending surgeon): "Appreciate you coming down."

Attending surgeon (talks to Sr ED): "I came when I got the page."

Sr ED (talks to Attending surgeon, enthusiastically): "You ran the thing, man. You took over. I'm like, yeah, hold on, whatever."

Additionally, as we have observed, conflicts due to the differences of opinion were less likely to occur because both physicians were highly experienced. Data from interviews with ED physicians and senior surgeons also confirmed this finding. Unnecessary procedures were less likely as well. Before critical orders were given, physicians engaged in discussion to decide on the most appropriate approach. The team felt there was an order to the process and less unnecessary work, as shown in the following statement:

"*Based on my experience, when I have two attendings there, no matter what services they are, we don't do near as many labs or x-rays, they actually collaborate pretty well.*" [Nurse#4]

When attending surgeons were present, we also observed instances of intra-disciplinary intervening model occurring between the surgeon and the surgical team leader. That is, the attending surgeon provided real-time feedback on the leader's performance and advised on certain steps of procedures during the resuscitation process.

5. Discussion

We rated the five leadership structures that we have identified on three dimensions of team performance: defined leadership, agreement (or lack of conflict in decision making), and appropriate care delivery, with qualitative scores of low, medium, and high (Table 2). The ratings were constructed based on our observations and were confirmed by data from interviews with trauma team members. Additionally, domain experts on our research team, who reviewed the videos and participated in many resuscitation events we have observed, validated our rating scheme based on their expert opinion. We also applied this rating scheme during prospective reviews of trauma events to ensure the appropriate fit.

The key characteristics of each leadership structure are:

- *Defined leadership* dimension assesses whether or not the team members have a clear understanding of who is in charge of the resuscitation process. Our observations showed that teams lead by decision makers from one discipline (intra-disciplinary solo decision-making and intervening models) or by two senior attending physicians from several disciplines (cross-disciplinary collaborative decision-making) were able to identify their team leader. Ambiguities about the designated trauma leader were observed in shared intervening and parallel decision-making models. In both cases, the more experienced ED physicians intervened and assigned tasks to other team members, sometimes without any consultation with the surgical leader. Team members were often confused in this situation about whom to listen to or whom to report

Table 2 – Ratings for leadership structures based on defined leadership, agreement (lack of conflict), and appropriate care (e.g., unnecessary procedures).

Structure aspect	Intra-disciplinary		Cross-disciplinary		
	Solo	Shared intervening	Shared intervening	Shared parallel	Shared collaborative
Defined leadership	High	High	Med	Low	High
Agreement	High	High	Low	Low	High
Appropriate care	Med	High	Med	Med	High

observations and task completions. The weakest leadership dimension was observed in cross-disciplinary parallel model, in which both surgical leaders and ED physicians issued independent task orders to other team members.

- *Agreement* dimension assesses the likelihood of conflict arising among the leadership roles due to the differences of opinion. Solo decision-making model lacked conflict because only one physician was in charge. As our observations revealed, likelihood of conflict was particularly high when leaders came from different disciplines (cross-disciplinary intervening and parallel models) and when leadership hierarchical structure was less clear. The presence of an experienced surgeon in the cross-disciplinary collaborative model helped mitigate potential conflicts, even though this model involved leaders from different disciplines.
- *Appropriate care* dimension assesses the likelihood of performing unnecessary procedures. Our observations suggested that the most appropriate care was given in cases when more than one leader was present, either in intra-disciplinary or cross-disciplinary scenarios. Errors were more likely in the solo leadership model because of the absence of leadership collaboration. Unnecessary procedures were also more frequent in cross-disciplinary scenarios where the potential for agreement was low.

In summary, the main contribution of this paper is in identifying leadership structures and their effects on teamwork, information sharing, and appropriate care delivery. Our findings have practical implications for efficient teamwork and optimal patient care, including implications for training, design of organizational practices, and technology design. For technology design, a key implication is that different leadership structures require different kinds of information. For example, leaders in intra-disciplinary solo-decision making model need information about completed evaluation steps and findings from each step to ensure timely decisions about complex procedures. ED physicians in cross-disciplinary intervening or parallel leadership models need information about surgical residents' expertise and level of training. In contrast, surgical residents in these two leadership models need information about children-specific treatments and procedures. Overall, all leadership structures could benefit from improved retention of and access to patient information.

Because different leadership structures exhibit different weaknesses, technology design should attempt to address the weakest aspects of each. In case of solo leadership, the emphasis should be on ensuring that important steps are not missed and unnecessary procedures or incorrect medication orders are avoided. In case of cross-disciplinary intervening and parallel models, the greatest concern is a high potential for conflict, mostly about recommended treatments and procedures. It appears that in both cases, information technology has the potential to assist with delivering appropriate care and mitigating conflict by providing easy access to information databases or efficient communication with remote experts who can help resolve the conflicting decisions. Because a computerized system cannot automatically recognize the leadership structure, the system should be designed to provide these functional features for general scenarios.

We believe that a key component of technology assistance for different leadership structures will be improved situational awareness. Improved situational awareness will help team members correctly identify the leadership roles, changes in patient status, the tasks that have been done, and the newly ordered tasks. We have already taken steps towards this objective with two different technologies. First, as mentioned in Section 4.3, we instituted the practice of wearing self-adhesive paper role-tags indicating members' roles at CNMC. Our observations of role-tags usage revealed that the current low-tech solution failed to achieve improved role identification in the events that were identified as being the most in need of it [27]. The main problem was that role-tagging required work by trauma team members (e.g., they needed to remember to take the role-tags on their way to the trauma room). To enable more efficient role-identification in this environment, we suggest using smart badge technology to transmit the worker's role-based information from their current, employee badges to another display. Smart badges have so far been used for the purposes of location-based tracking [28], facilitating person-to-person interactions at large, conference-type meetings [29], and decision-making [30], and could be adapted to support role-identification during trauma resuscitation. Second, we designed a prototype system consisting of digital pen and paper technology and wall displays to improve trauma team's situational awareness [31]. We believe that displaying information about current patient status, administered medications and fluids, and vital signs trends could facilitate information flow among team members, and improve overall teamwork, decision making and information sharing.

5.1. *Limitations*

Our study has two limitations. First, institutional IRBs imposed different constraints on data access, resulting in somewhat different data collection and analysis for the two centers. Because of time-limited availability of videos at RWJ, we were unable to review a larger number of resuscitations. We

produced detailed transcripts for 18 events, which allowed detailed analysis of questions posed among the team members. Video recording at CNMC is part of the performance improvement efforts and no time limits were imposed on video analysis. This enabled us to review a larger number of videotaped resuscitations and to transcribe only parts of events. Although we produced detailed notes for each event, we did not have sufficient data for detailed analysis of questions.

Second, while the use of two centers provided perspective not gained by analysis of a single site, some of our findings may still be specific to these two trauma centers. Additionally, trauma resuscitation has some unique characteristics and it may be difficult to generalize our results to generic medical care, and from medical care to other domains. Resuscitation events are fast-paced and short, with frequently changing team members who may not know each other. Nonetheless, we believe that our study resulted in important insights about team leadership and hypotheses about leadership structures in a dynamic teamwork setting.

Summary points

What was already known

- The presence of an identified and experienced attending surgeon enhances team performance and ensures quality of patient care.
- Many trauma centers have strong emergency medicine programs, with emergency medicine physicians regularly assuming leadership roles.
- Prior research on team structures emerging during trauma resuscitation, but not on leadership structures.

What the study has added to our knowledge

- There are five leadership structures in trauma resuscitation, grouped under intra-disciplinary leadership (surgical leadership only) and cross-disciplinary leadership (shared leadership between surgical and emergency medicine physicians).
- Shared leadership between physicians from different disciplines with different levels of experience often leads to conflict, reduces teamwork efficiency and lowers the quality of care.

6. Conclusions

We conducted observational studies at two Level 1, teaching trauma centers (one of which is a dedicated pediatric trauma center), to examine leadership structures and their effects on trauma team performance and patient care. We identified five common leadership models, grouped under two broad leadership structures: intra-disciplinary and cross-disciplinary leadership. Within intra-disciplinary leadership structure, two decision-making models emerged: solo decision-making and intervening decision-making. Both were primarily observed at the adult trauma center, where surgeons are solely responsible for leadership. Rare instances of solo decision-making were also observed at the pediatric trauma center. Within cross-disciplinary leadership structure, three decision-making models emerged: intervening decision-making, parallel decision-making and collaborative decision-making. All three were primarily observed at the pediatric trauma center, where trauma leadership is shared between surgery and ED departments. Instances of intra-disciplinary intervening decision-making were also observed at the pediatric center when an attending surgeon was present.

Our findings indicate that weaknesses of different leadership structures manifest themselves in unnecessary procedures, skipped evaluation steps or incorrect medication orders. These inefficiencies are particularly problematic when leadership is shared between physicians from different disciplines with different levels of experience, which may often lead to conflict, reduce teamwork efficiency and lower the quality of care.

Author contribution

Aleksandra Sarcevic, PhD provided substantial contributions to conception and design of the studies, to acquisition of data, and to analysis and interpretation of data. She conducted observational studies at both research sites, and collected and analyzed the data. She led group discussions of emerging themes from the data and revised initial set of themes until the final set of themes emerged. She drafted the article and revisited it critically for important intellectual content. She was the leader in drafting the article. She then continued with revisions by incorporating feedback provided by co-authors. She read the final version of the article and approved it for submission.

Ivan Marsic, PhD provided substantial contributions to conception and design of the studies, to acquisition of data, and to analysis and interpretation of data. He provided logistical support for data collection and contributed to data collection at the first research site. He also contributed to group discussions of emerging themes from the data. He drafted the article and revisited it critically for important intellectual content. He contributed significantly to revising initial draft of the article as well as the subsequent versions of the article. He provided critical review of the article and revisited it each time new version was sent out to the group. He read the final version of the article and approved it for submission.

Lauren J. Waterhouse, BS provided substantial contributions to analysis and interpretation of data: Lauren contributed to data analysis, i.e., reviewing video records of live trauma resuscitations. She also contributed to group discussions of emerging themes from the data. She reviewed the article for important intellectual content. She provided critical review of the draft and subsequent versions of the article. She read the final version of the article and approved it for submission.

David C. Stockwell, MD, provided substantial contributions to interpretation of data. He contributed to group discussions of emerging themes from the data. He reviewed the article for important intellectual content. He provided critical review of

the article and revisited it each time new version was sent out to the group. He read the final version of the article and approved it for submission.

Randall S. Burd, MD, PhD, provided substantial contributions to interpretation of data. He contributed to group discussions of emerging themes from the data. He reviewed the article for important intellectual content. He contributed significantly to revising versions of the article. He provided critical review of the article and revisited it each time new version was sent out to the group. He read the final version of the article and approved it for submission.

Conflict of interest statement

The authors do not have any financial and personal relationships with other people or organizations that could inappropriately influence or bias this work.

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REFERENCES

[1] S.E. Kogler Hill, Team leadership, in: P.G. Northouse (Ed.), Leadership: Theory and Practice, Sage, Thousand Oaks, CA, 2006, pp. 207–235.
[2] G.L. Stewart, C.C. Manz, Leadership for self-managing teams: a typology and integrative model, Human Relations 48 (7) (1995) 747–770.
[3] S.G. Cohen, G.E. Ledford, The effectiveness of self-managing teams: a quasi-experiment, Human Relations 47 (1) (1994) 13–43.
[4] E. Sundstrom, K.P. de Meuse, D. Futrell, Work teams: application and effectiveness, American Psychologist 45 (2) (1990) 120–133.
[5] S.W.J. Kozlowski, S. Gully, E. Salas, J. Cannon-Bowers, Team leadership and development: theory, principles, and guidelines for training leaders and teams, in: M.M. Beyerlein, D.A. Johnson (Eds.), Advances in Interdisciplinary Study of Work Teams: Team Leadership, JAI Press, Greenwich, CT, 1996, pp. 253–291.
[6] A.C. Edmondson, Speaking up in the operating room: how team leaders promote learning in interdisciplinary action teams, Journal of Management Studies 40 (6) (2003) 1419–1452.
[7] B.J. Avolio, D.I. Jung, N. Sivasubramaniam, Building highly developed teams: focusing on shared leadership processes, efficacy, trust, and performance, in: M.M. Beyerlein, D.A. Johnson (Eds.), Advances in Interdisciplinary Study of Work Teams: Team Leadership, JAI Press, Greenwich, CT, 1996, pp. 173–209.
[8] J.B. Carson, P.E. Tesluk, J.A. Marrone, Shared leadership in teams: an investigation of antecedent conditions and performance, Academy of Management Journal 50 (5) (2007) 1217–1234.
[9] P. Gronn, Distributed leadership as a unit of analysis, Leadership Quarterly 13 (4) (2002) 423–451.
[10] M. Mayo, J.R. Meindl, J.C. Pastor, Shared leadership in work teams: a social network approach, in: C.L. Pearce, J.A. Conger (Eds.), Shared Leadership: Reframing the Hows and Whys of Leadership, Sage, Thousand Oaks, CA, 2003, pp. 193–214.
[11] A. Mehra, B. Smith, A. Dixon, B. Robertson, Distributed leadership in teams: the network of leadership perceptions and team performance, Leadership Quarterly 17 (3) (2006) 232–245.
[12] D.C. Stockwell, A.D. Slonim, M.M. Pollack, Physician team management affects goal achievement in the intensive care unit, Pediatric Critical Care Medicine 8 (6) (2007) 540–545.
[13] K. Catchpole, A. Mishra, A. Handa, et al., Teamwork and error in the operating room analysis of skills and roles, Annals of Surgery 247 (4) (2008) 699–706.
[14] K. Mazzocco, D.B. Petitti, K.T. Fong, et al., Surgical team behaviors and patient outcomes, American Journal of Surgery 197 (5) (2009) 678–685.
[15] W.S. Hoff, P.M. Reilly, M.F. Rotondo, J.C. DiGiacomo, C.W. Schwab, The importance of the command-physician in trauma resuscitation, Journal of Trauma 43 (5) (1997) 772–777.
[16] S. Yun, S. Faraj, H.P. Sims Jr., Contingent leadership and effectiveness of trauma resuscitation teams, Journal of Applied Psychology 90 (6) (2005) 1288–1296.
[17] Y. Xiao, F.J. Seagull, C.F. Mackenzie, K. Klein, Adaptive leadership in trauma resuscitation teams: a grounded theory approach to video analysis, Cognitive Technique Work 6 (3) (2004) 158–164.
[18] Y. Xiao, F.J. Seagull, C.F. Mackenzie, K. Klein, J. Ziegert, Distant leadership under stress [internet]. Final report for U.S. Army Research Institute for The Behavioral and Social Sciences; 2003 [cited 2010 April 19]. Available from: http://hfrp.umaryland.edu/reports/Distant Leadership Final Rpt.pdf.
[19] K. Klein, J. Ziegert, A. Knight, Y. Xiao, Dynamic delegation: shared, hierarchical, deindividualized leadership in extreme action teams, Administration Science Quarterly 51 (4) (2006) 590–621.
[20] American College of Surgeons, Resources for Optimal Care of the Injured Patient, American College of Surgeons, Chicago, IL, 2006.
[21] American College of Surgeons, Advanced Trauma Life Support® (ATLS®), 8th ed., American College of Surgeons, Chicago, IL, 2008.
[22] J.R. Clarke, B. Spejewski, A.S. Gertner, B.L. Webber, C.Z. Hayward, et al., An objective analysis of process errors in trauma resuscitations, Academy Emergency Medicine 7 (11) (2000) 1303–1310.
[23] J. Corbin, A. Strauss, Grounded theory research: procedures, canons, and evaluative criteria, Qualitative Sociology 13 (1) (1990) 3–21.
[24] A. Sarcevic, I. Marsic, M.E. Lesk, R.S. Burd, Transactive memory in trauma resuscitation, in: Proc ACM Conf on Computer Supported Cooperative Work (CSCW '08), San Diego, CA, November 8–12, ACM Press, New York, 2008, pp. 215–224.
[25] R.L. Helmreich, On error management: lessons from aviation, BMJ 320 (7237) (2000) 781–785.
[26] J.B. Sexton, E.J. Thomas, R.L. Helmreich, Error, stress and teamwork in medicine and aviation: Cross sectional surveys, British Medical Journal 320 (7237) (2000) 745–749.
[27] A. Sarcevic, L.A. Palen, R.S. Burd, Coordinating time-critical work with role-tagging, in: Proc ACM Conf on Computer Supported Cooperative Work (CSCW '11), Hangzhou, China, March 19-23, ACM Press, New York, 2011.
[28] Q. Jones, S.A. Grandhi, L. Terveen, S. Whittaker, People–to–people–to–geographical–places: the P3 framework for location-based community systems, Computer Supported Cooperative Work 13 (3–4) (2004) 249–282.

[29] M. Laibowitz, J. Gips, R. Aylward, A. Pentland, J.A. Paradiso, A sensor network for social dynamics, in: Proc. ACM Conf on Information Processing in Sensor Networks (IPSN '06), April 19–21, Nashville, TN, ACM Press, New York, 2006, pp. 483–491.

[30] A. Pentland, Socially aware computation and communication, IEEE Computer 38 (3) (2005) 33–40.

[31] A. Sarcevic, N. Weibel, J.D. Hollan, R.S. Burd, TraumaPen: a paper-digital interface for information capture and display, submitted to ECSCW 2011.