Management of a critical downtime event involving integrated electronic health record

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Abstract

***Background*:** There are few descriptions of management of unplanned hospital-wide digital downtime and impact on patient care in health literature.

***Aim*:** The aim of this study was to undertake a qualitative review of a prolonged critical technology downtime event in an Australian hospital in 2017.

***Methods*:** Inductive content analysis was conducted on data collected through face-to-face, semi-structured, individual interviews conducted with nine hospitals employees (five nurses with direct-care/operational responsibilities, and four executive staff, including nursing) who played a role in the incident.

***Findings*:** Analysis of the data using an open-source R package led to the extraction of 139 codes, 13 first-level categories, and 4 main categories. Main categories extracted were: impact of event, response to the event, resilience and institutional reserve, and challenges and learnings.

***Discussion*:** The overall experience for interview participants was positive. Effective communication methods, particularly vertical communication, enabled multi-disciplinary teams (comprising nursing, medical and pharmacy personnel) to safely transition back from downtime paper records to the integrated electronic health record with no harm to patients. Participants

identified teamwork contributed to a sense of comradery with clinical colleagues and executive staff. Contingency planning and training are essential for ensuring safe and effective management of technology downtime events.

***Conclusion*:** The prolonged digital disruption and subsequent recovery was managed effectively using a face-to-face communication and support approach. This approach reduced the impact of the digital downtime and ensured patient safety. The data analysis strategy was enhanced using an computer-assisted qualitative data analysis software.

Keywords: Electronic health records; Medical informatics; Health information technology; Content analysis; Downtime; Computer security

Summary of relevance

Problem or issue

- Cyber breaches represent a critical threat to integrated electronic health records worldwide.
- Unexpected digital 'downtime' events – planned or unplanned periods of time when the ICT system is unavailable for use – pose a threat to patient safety, potential loss or compromise of data, and disruptions to continuity of health care delivery.

What is already known

- Information and communication technology is transforming healthcare.
- While there is guidance in health literature on contingency planning for digital downtime, there are few descriptions on the management and impact of downtime events on health service delivery.

What this paper adds

- Provides a 'first-hand' account of an unprecedented disruption to the integrated electronic health record of a large hospital.
- Informs healthcare facilities about potential inefficiencies in operational functions and suggests adaptations to enhance immunity against unplanned downtime vulnerabilities to ensure patient safety and data security.

In industrialised nations, information and communication technology (ICT) is transforming healthcare. Paper-based document management systems traditionally used in health settings are rapidly evolving to integrated electronic health records (iEHR) (Jha, Doolan, Grandt, Scott, & Bates, 2008). With large-scale deployment of ICT infrastructure, security and data-protection risks have increased (Coventry & Branley, 2018).

Cyber breaches are an increasing threat to iEHR worldwide, resulting in inaccessibility of critical clinical information and functions (Clarke & Youngstein, 2017; Healthcare Information & Management Systems Society, 2019). Facilities are also susceptible to sudden ICT outages due to internal disruptions such as hardware failures (Coffey, Postal, Houston, & McKeeby, 2016), software bugs (Genes, Chary, & Chason, 2013) and failed ITC upgrades (Wretborn, Ekelund, & Wilhelms, 2019). Unexpected system outages pose a threat to patient safety, potential loss or compromise of data, and disruptions to continuity of health care delivery (Harrison, Siwani, Pickering, & Herasevich, 2019; Larsen, Fong, Wernz, & Ratwani, 2017; Wang et al., 2016; Wretborn et al., 2019).

Despite cybersecurity concerns, adoption of iEHR is vital for transforming the standard of patient care (Raposo, 2015). Hence, a comprehensive implementation design, along with training and preparedness for nurses and other health professionals, is vital for effective and seamless integration of ICT in the healthcare environment (Coventry & Branley, 2018; Ronquillo, Winterholler, Cwikla, Szymanski, & Levy, 2018). Equally important is contingency planning for 'downtime' events–planned or unplanned periods of time when the ICT system is unavailable for use (Sittig, Gonzalez et al., 2014). As health organisations become more dependent on digital records, technical and organisational policy and procedures need to be established to guide efficient and safe transition from digital to paper-based and back again (Kashiwagi et al., 2017). While guidance for contingency planning is available (Jalali, Russell, Razak, & Gordon, 2018; Sittig, Ash et al., 2014), there are few descriptions of iEHR downtime in health literature (Wretborn et al., 2019). A 'first-hand' account of an unprecedented disruption to iEHR in a large hospital can be a valuable learning resource. It can inform healthcare facilities to potential inefficiencies in downtime operational functions and suggest adaptations to enhance immunity against unplanned downtime vulnerabilities (Sittig, Gonzalez et al., 2014).

The current study details an unplanned hospital-wide ICT downtime of six days at a major teaching hospital in Australia. The downtime event was precipitated by an international cyberattack in May 2017 (named 'WannaCry') which had significant impact upon health services in the United Kingdom (Clarke & Youngstein, 2017; Comptroller & Auditor General, 2017). Preemptive security response by ICT staff led to unexpected and undetected accessibility limits to iEHR and concurrent use of paper and electronic documentation of patient care, representing significant risks to patient safety. An internal emergency response was initiated and access to inpatient iEHR suspended. Relative to source, nature, and duration, the incident has no precedent in academic or grey literature. Strategies to ensure safe and effective patient care had to be quickly developed and implemented. The aim of this study was to undertake a qualitative review of the impact and management of the ICT downtime event.

1. M~~ATERIALS AND METHODS~~aterials and methods

1.1. Design

The Consolidated criteria for reporting qualitative studies (COREQ) checklist was used to guide the reporting of this study (Tong, Sainsbury, & Craig, 2007). Inductive content analysis was conducted to assess the impact and management of an iEHR downtime event at 23–28 May 2017. Widely used in health research, content analysis reduces data to meaningful concepts by creating categories through a process of abstraction for

previously unexplored phenomena (Elo & Kyngäs, 2008; Elo et al., 2014) The method provides content-sensitivity and broad description in terms of concepts and categories.

1.2. Setting

The study was conducted in a large Australian 700-bed quaternary hospital providing acute medical, surgical, mental health, cancer, rehabilitation and allied health services. The hospital had 110,226 admissions in 2016~~-2017, employed over 5,~~–2017, employed over 5500 staff, and conducted 20,269 surgeries. Full rollout of advanced iEHR capability was completed just two months ~~prior to~~before the incident and included an established schedule of four planned downtimes per annum. All patient care processes were supported and recorded within a digital environment including clinician documentation, care planning, clinical decision support, diagnostic orders, discharge management, and medication administration. The management of both planned and unplanned iEHR downtime events was detailed in a number of hospital guidelines to ensure the continuation of operations and optimisation of patient safety and risk management strategies via a chain of command. These guidelines included step-by-step procedures and checklists for downtime coordinators (the nurse unit manager or delegate of each ward or service) and staff (nursing, medical, radiology, pathology and administrative) to utilise during the recovery phase. As unscheduled downtimes were classified as internal emergencies, an iEHR business continuity strategy was embedded within the hospital's disaster management plan.

Following initial review by the health service Human Research Ethics Committee, the project was considered to be exempt from full ethical review (HREC/17/QPAH/451; HREC/17/QPAH/539).

1.3. Participants

Nine employees who played a role in the incidence were approached by, or recommended to the lead researcher to share their experience during this time. While all individuals were free to refuse, all agreed to participate. Nursing participants' roles included a nurse executive, three nurse leaders responsible for clinical and operational matters, and two direct-care nurses. Other participants comprised a senior executive officer with organisational responsibilities, a medical and iEHR specialist, and a pharmacy team leader. Four participants with organisation responsibilities were members of a larger incident team specifically assembled to manage the event.

1.4. Data collection

Face-to-face, semi-structured, individual interviews were conducted at participants' workplace between 19 July~~ – –~~31 August 2017, and digitally recorded and transcribed verbatim by a professional transcription service. Each interview lasted 20~~-66 minutes (M =42 minutes~~–66 minutes (*M* = 42 min). Open-ended questions guided the interviews, including: "Can you tell me about your experiences during the recent shut-down of the iEHR?"; "What were the positive and negative aspects of how this critical event was managed?; "What level of support did you receive from nursing, medical, allied health colleagues in your work environment?"; "What level of support did you receive from the division of surgery and the organisation

during this critical event?". All participants were provided the opportunity to review and make changes to their transcribed interview ~~prior to~~before analysis.

1.5. Data analysis strategy

Analysis utilised data corpus from nine interview transcripts and an inductive content analysis approach based on emergent main categories to describe the phenomenon (Elo & Kyngäs, 2008). Computer-assisted qualitative data analysis software (CAQDAS) can be a valuable tool to enhance *transparency*, *validity*, *rigor* and *trustworthiness* of qualitative research projects (Woods, Macklin, & Lewis, 2016). An open-source R package (R Qualitative Data Analysis, RQDA: Huang, 2016) was used for this study (see Supplement 1 for RQDA application).

1.6. Coding

Transcribed interview files were imported to RQDA. Every interview was read multiple times to construct a general understanding of content and meaning. After each interview, preliminary impressions were coded. As more interviews were read, new codes were added, renamed, and merged reiteratively to refine codes to best represent the contextual information (Elo & Kyngäs, 2008). Time-related text was indexed to allowed post-hoc extraction of chronology of events.

1.7. Categories (Code abstraction)

Codes were aggregated into first-level and then main categories using a process of abstraction. Similar to the coding process, categories were refined reiteratively to identify higher-order groupings and contextualisation (Elo & Kyngäs, 2008). The process of deriving meaningful understanding of categories was augmented by network analysis and visualisation carried out using R (refer Supplement 1) (R Core Team, 2013).

2. Results

Analysis of the data led to extraction of 139 codes, 13 first-level categories, and 4 main categories. Examples of the formation of categories from codes by inductive content analysis is shown in Table 1. A representation of the broad chronology of events was produced by reviewing and consolidating time frame of events between participants (Fig. 1).

alt-text: ~~.~~Table 1

Table 1

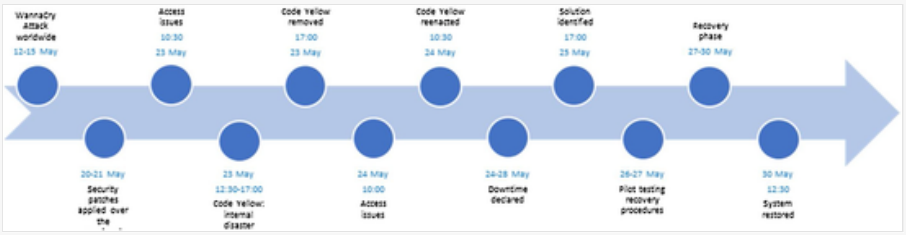
The table layout displayed in this section is not how it will appear in the final version. The representation below is solely purposed for providing corrections to the table. To preview the actual presentation of the table, please view the Proof.

Sample data extract containing "Example text", initial "Code", developed "First Level Categories", and overarching "Main Categories"

Example text	Code	First-level Category	Main Category
In fact, people are pretty good in saying look maybe you should take a couple of hours off. Go and sit in the sun	Supportive	Human values and relations	Resilience and institutional reserve
There are some lessons learned but there was no patient harm.	No patient harm	Focussing on safety	Response to adverse event
This was obviously unscheduled, it was unpredictable and also it was partial...	Access disruption	Experiencing difficulties	Impact of the Event
I think this is going to be a problem for the future in where people move between hospitals, between a digital hospital and another [redacted] they've going to have to re-school themselves in or at least have an orientation to how to write in paper records just as much as we have to orient people coming in in how to use the electronic record.	Orientation for paper	Lessons for future	Challenges and learnings

alt-text: Fig. 1

Fig. 1



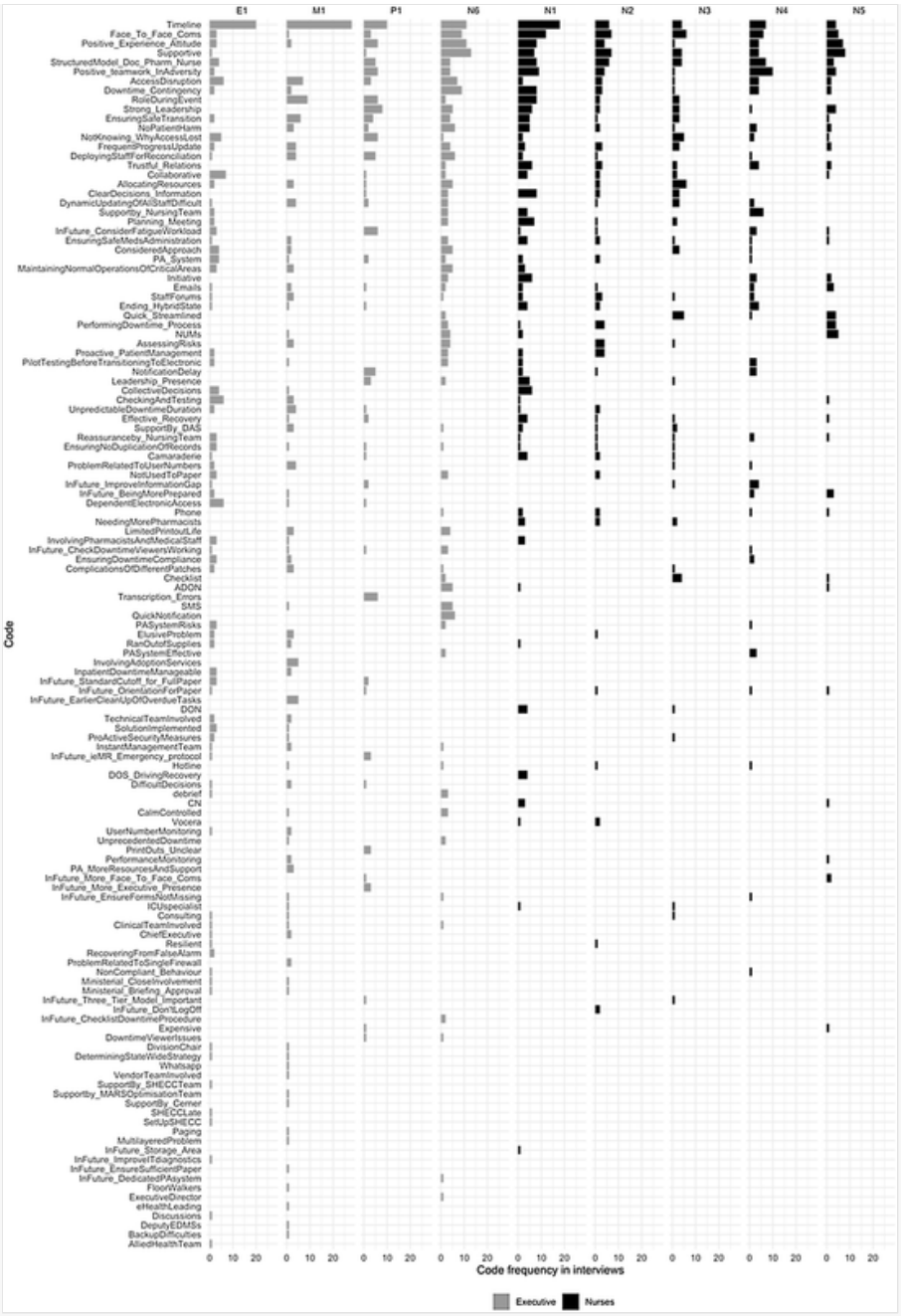
Timeline of activities during the downtime event (WannaCry: ransomware attack; Code Yellow: internal emergency; Downtime: access to inpatient iEHR suspended).

2.1. Occurrence of codes

Codes were segregated by role of participants involved in senior organisation responsibilities (executive) and operational/direct care nursing staff (nurses). The frequency of codes provided a global picture of the content of these groups (Fig. 2). For example, timelines and codings associated with strategising were better represented in the executive group, while operational/direct care nursing staff emphasised teamwork, supportive network and positives from the experience. Codes representing safety were equally distributed across both groups.

alt-text: Fig. 2

Fig. 2



Barplot of coding frequency between interviews. Coloured by groups, executives (4 interviews) and direct-care nurses (5 interviews).

2.2. Main categories

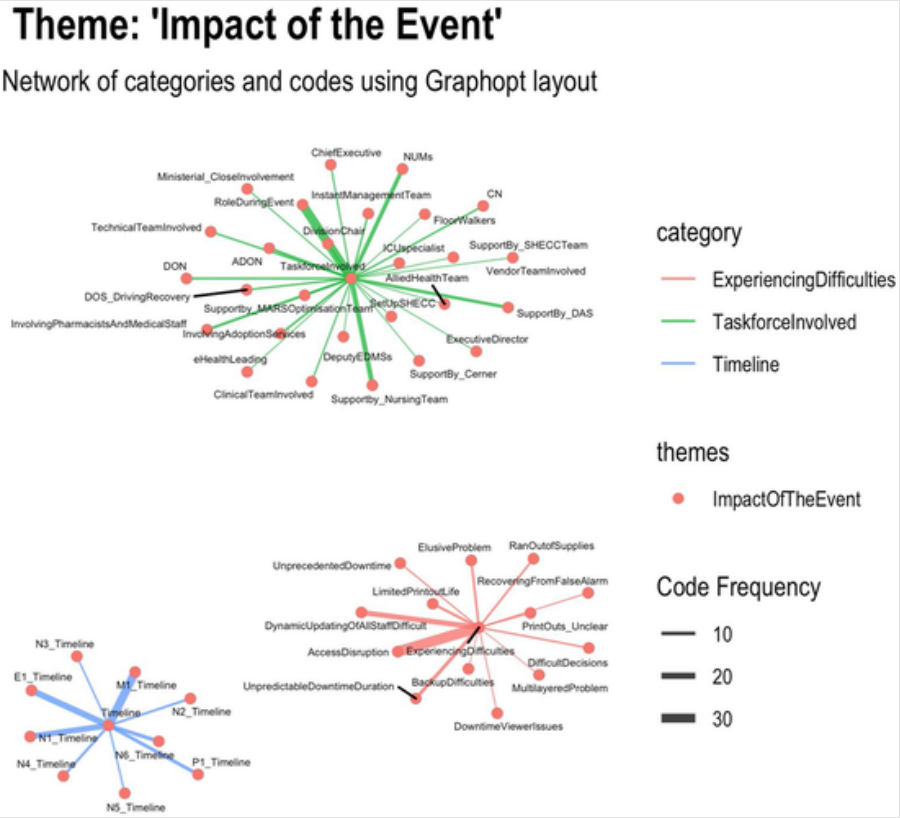
Four main categories extracted were: impact of the event; response to the event; resilience and institutional reserve and; challenges and learnings.

2.2.1. Impact of the event

This category captures the initial difficulties of iEHR access disruption, taskforce involved, and the chronology of events (Fig. 3).

alt-text: Fig. 3

Fig. 3



Network visualisation of codes and categories representing ‘Impact of the event’. Edge links are weighted by code frequency, edge line colours correspond to first-level categories, and node colour corresponds to main category.

At the point of impact, the situation was challenging with intermittent login difficulties and multi-layered problems with a transient sense of recovery (false-alarms).

> “*We were getting some reports through of difficulties logging in, but in fact people who were already logged in were okay and it was only really as new people came in that they were having difficulty in accessing.*~~" (E1_Aug24_2017)"~~” (E1_Aug24_2017)
>
> “*Then we thought it was back up and running and we started to reconcile all the patients and then it went down again*~~.".~~” (N1_July19_2017)

Regular updates to staff were critical but difficult at the executive level due to size of the campus and functionally segregated staff. Despite availability of a variety of communication tools, no single tool was able to get across all staff members simultaneously. Verbal communication was more effective than emails:

> ~~"~~“*You could ring everybody and get people to filter it down but that takes time, or you could send emails. Well half the people are working clinically, they're not actually looking at their emails. Or you could do a run around but to get around*

the organisation this big, that would take some time." (E1_Aug24_2017)"." (E1_Aug24_2017)

"So verbally first and then executive were sending out emails that weren't accessed, so staff wouldn't have had time to read their emails." ." (N4_July24_2017)

Multilayered challenges included limited life of downtime printouts, false alarms, and unpredictability of downtime.

""So, we got to a point in the downtime where the medications that were in the downtime viewer were going to expire." (N6_Aug3_2017)"." (N6_Aug3_2017)

"we weren't sure of the period of time we were going to be down for." ." (N2_July19_2017)

A large taskforce was involved to deal with the impacts felt during iEHR disruption and provide expert support and rapid response during the critical event (Fig. 3, 'TaskforceInvolved').

2.2.2. Response to the event

Defines response by strategic planning, communication tools used, patient safety, and identification of solutions (Fig. 4).

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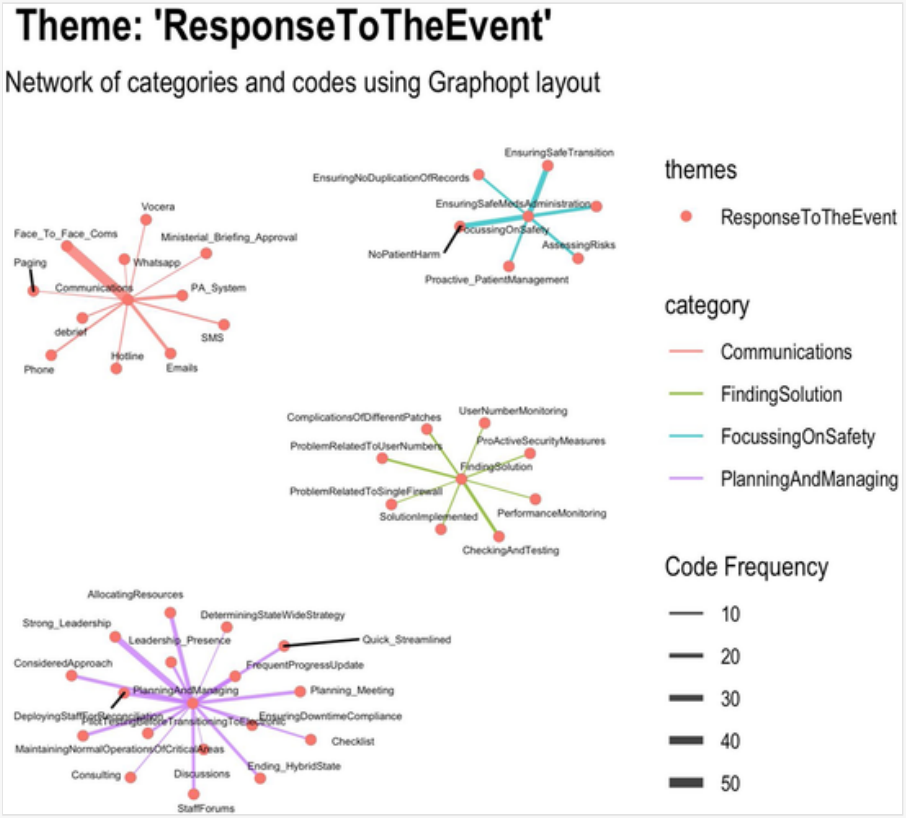
Fig. 4



Network visualisation of codes and categories representing ‘Response to the event’. Edge links are weighted by code frequency, edge line colours correspond to first-level categories, and node colour corresponds to main category.

Communication tools such as text messages, face-to-face, phone, emails, social platforms, and the emergency public announcement (PA) system were deployed. Task-specific mobile device carried by nursing staff proved to be efficient in rapid updating. Use of the PA system was successful, however all participants described ‘face-to-face’ communication most effective, direct, and reassuring.

> "...“ ...*it's easy to have a very quick conversation ... I think that personal approach and the reassurance for anybody who had concerns* ..." (E1_Aug24_2017)" ...” (E1_Aug24_2017)
> “*He walked around and checked up on the teams ... Even a representative from that company walked around and - couldn't really do too much to help out but walked around to make sure people were doing okay*." ." (P1_Aug23_2017)

The PA system was considered carefully despite its effectiveness in updating as there may be potential implications in a healthcare setting and patient care.

> "“*I think it's necessary, for the people who didn't catch the other forms of communication*." ." (P1_Aug23_2017)
> However, initially they failed to use the loudspeaker system because I believe they worry about causing distress to the patients and family members in the hospital." (N4_July24_2017)

Proactive measures in preparation for a potential cyberattack was suggested to have inadvertently caused the issue.

> "“...*as a result of preparing for the potential cyberattack that in fact created our problem. It was one of those hundreds of patches that we put in that saw our own staff logins as a threat*." ." (N6_Aug3_2017)

Consequently, a solution in terms of a new firewall was instituted.

Participants noted that successful recovery was due to organisational responsiveness in terms of strategic resource allocations to maintain critical infrastructure without interruption and with no impact on patients.

> "“*So, we said we're going to go completely to downtime for our inpatient areas. We'll try and maintain our emergency department and our outpatient functions and see if that helps the overall numbers*." ." (E1_Aug24_2017)

Furthermore, strong leadership presence, clear decisions, and ‘leading by example’ helped recovery and motivated recovery teams.

> "*That just makes you feel like I want to do it too because...they were both so engaged and ‘what can we do’, and energised with the whole process, I think that*

> *just leads by example. It's just so strong and such a good presence.*" (N1_July19_2017)

Establishing a checklist was one of the strategies implemented for recovery, which proved useful according to the participants.

> "*We had a checklist that was given to us to say, the nurse does - identifies patients that are for conversion...I think having the checklist made it really clear what we needed to do...*" (N3_July19_2017)

The primary focus was to ensure transition back to digital without duplication of records or compromising safety in medication administration. Participants discussed activities of assessing risks and proactively managing patient care:

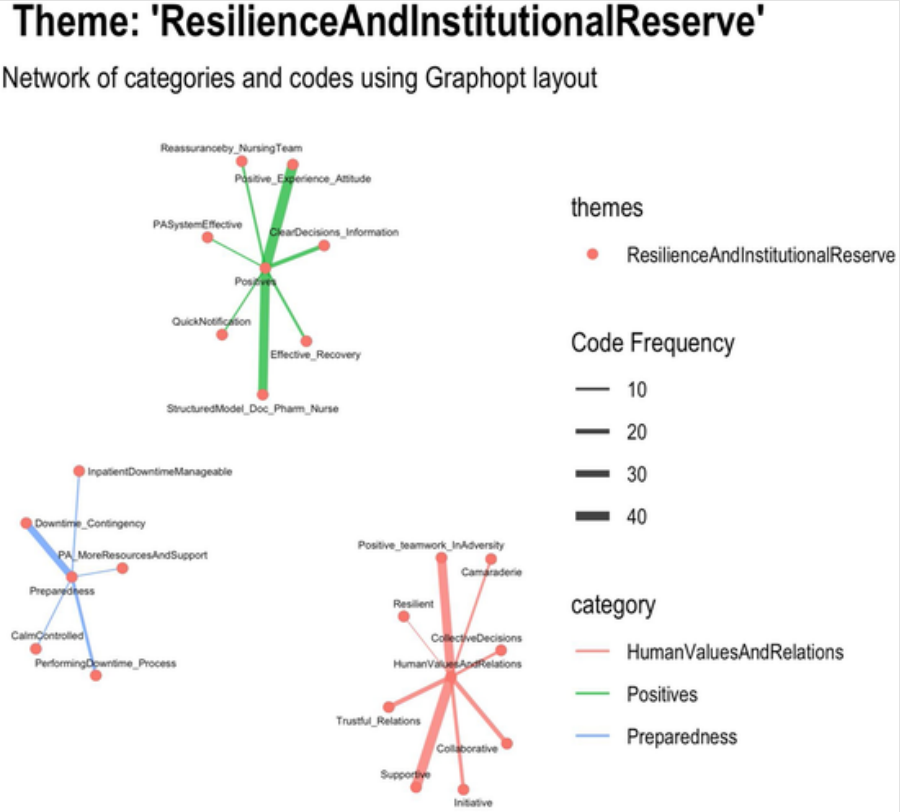
> "...*we also had a two-step process of transcribing the medications that were given that day, the last medication that was given, for continuity to make sure that the patient didn't receive a double dose for example within a certain time frame.*" (N3_July19_2017)

2.2.3. Resilience and institutional reserve

Defines adaptiveness and resilience of the organisation based on positive experiences, core human values, and preparedness (Fig. 5).

alt-text: Fig. 5

Fig. 5



Network visualisation of codes and categories representing 'Resilience and Institutional Reserve'. Edge links are weighted by code frequency, edge line colours correspond to first-level categories, and node colour corresponds to main category.

According to participants, core human values such as supportive, camaraderie, positive teamwork and strong trusting relations were motivating factors in successful recovery from this event.

> "... *one of the key words that was used was comradery...I think it brings people together. There's no doubt when you are forced in a situation where you need a high degree of cooperation*..." (E1_Aug24_2017)
>
> "*I was just proud to be a part of it to be honest. It just showed that it doesn't matter how bad things get, if we can work together you can get through it pretty much really. I love my job, I love where I work*..." (N5_July25_2017)

Converting the medication records back to digital was a complex procedure. A clear plan (checklist) of transcription checking by three healthcare professionals (nursing, medical, pharmacy) working as a team helped transition back to normal operations. Transcription back to digital records was the most crucial period with a huge bearing on patient safety. One participant explained the actual process in more detail:

> "... *how we did that physically is we got charts from patients' bedsides. We worked room by room and allocated charts to the residents or the medical officer that was present for transcription. Once they were done, we handed it to the pharmacist to review the chart. They would put a digital hospital sticker and then identify with us to let them know that this patient has been converted. So, it would go on the record to say this person has been converted. Then we would go to the bedside and*

communicate with the nursing staff and on to the patient as well to say that they're now back on the digital record." (N3_July19_2017)

Overall, the participants describe this event as a positive experience where teams worked together supportively without affecting critical aspects of hospital function:

"*–There are some lessons learned but there was no patient harm...we've just shown that we can have a downtime and it doesn't affect patient harm and it doesn't affect too much the business of a big hospital.*" (M1_Aug31_2017)

A number of participants noted that due to the downtime contingency plans that were in place it was easier to deal with iEHR access failure in a calm and controlled manner.

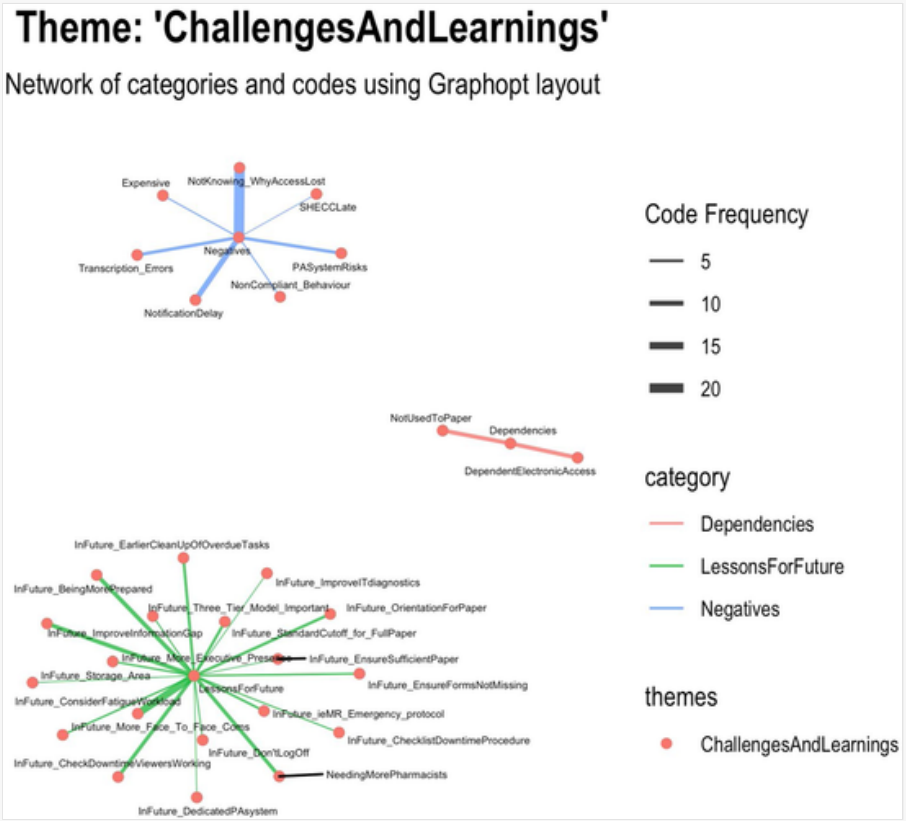
"*One of the positives was our staff were well prepared and versed in the downtime procedures.*" (N6_Aug3_2017)

2.2.4. Challenges and learnings

Defines the overall challenges and learnings based on key dependencies and negative experiences (Fig. 6).

alt-text: Fig. 6

Fig. 6



Network visualisation of codes and categories representing 'Challenges and Learnings'. Edge links are weighted by code frequency, edge line colours correspond to first-level categories, and node colour corresponds to main category.

Some participants noted that key dependencies such as the emergency departments and outpatient functions are heavily reliant on iEHR. Furthermore, familiarity with the efficacy and ease of electronic records meant that staff were dependent on iEHR access. Consequently, the impact of disruption to electronic systems was commensurate with the extent of reliance.

> "...*Just the familiarity with medications and all of the things that are associated with clinical care is just so much easier with the electronic record and people become used to that... You don't realise how automated things are now with the electronic record and the checking and all those things that go on within the record are not available in the paper system.*" (E1_Aug24_2017)

Some participants recognised instances when a staff member inexperienced in paper-based records were finding it difficult to prescribe medication on paper:

> "*The interesting part in that is I had a couple of staff going, what does that mean?... Because they had never not worked in the digital system...*" (N2_July19_2017)

Another participant felt that not knowing the cause of the disruption and delay in notification to go to full paper downtime could be improved in the future:

> "*One of the major issues was - my experience at the time, there was a delay with notification that we were switching from EHRs to go over to paper...* " (P1_Aug23_2017)

Workload and fatigue were acknowledged by executives seeking answers to how best to address 'burnout' and "maintain the organisation at that high level of readiness and responsiveness in these situations" (E1_Aug24_2017).

Other participants expressed their concerns:

> "*-We had a very high activity, high acuity workload at that time. I think the level of fatigue wasn't recognised...*" (N4_July24_2017)

Some participants expressed that having more practice with digital disruption during business hours would improve future resilience:

> "*In this case it's imperative for our staff to understand how we understand the downtime viewer and to understand how to do that. They have to practice with it and they have to know what's in the computer system, how to access the computer and what's in the downtime viewer box.*" (N4_July24_2017)

A similar approach as an emergency team designated for fire-related events could be implemented for iEHR disruption emergencies.

3. D~~ISCUSSION~~iscussion

This study described and analysed management of a critical ICT event at a large hospital, identifying core strengths to overcome challenges, and key learnings to improve future responses. Inductive content analysis of interview data of staff involved in the critical incident revealed four contextual categories pertaining to 1) impact of the event; 2) response to the event; 3) resilience and institutional reserve and; 4) challenges and learnings. Overall, the experience of the participants interviewed were predominantly *positive* premised on effective use of "face-to-face communications", "supportive" work environment at all levels, "positive teamwork" in adverse situations, "strong leadership" at all levels, and efficient and proactive "planning and management". Below is a summary of analysis findings including discussion of issues highlighted by participant comments.

To recap, the event commenced with transient problems with access, later identified as login-related. Diagnostics was difficult in the first 24-~~-~~48 hours, but the disruption was eventually linked to the application of multiple security patches to existing systems. Face-to-face communication was the most effective means of disseminating information although participants expressed a need for formalised communication infrastructure to allow instantaneous message delivery. The initial disruption involved concurrent use of paper and electronic records, classified as a 'dangerous zone' by a number of participants. Development and testing of a safety checklist enabled transition back to digital records without incident. Participants noted that, despite the extended downtime, clinical services continued without any noticeable interruptions or safety concerns.

3.1. Communication

Communication is acknowledged as a critical challenge and key focus for improvement by health facility stakeholders who have experienced unplanned downtime events (Coffey et al., 2016; Genes et al., 2013; Larsen et al., 2019; Primeau, 2018). Information sharing, a reciprocal process of sending and receiving information, predicts effective team performance (Mesmer-Magnus & DeChurch, 2009). In the initial stages of the event, the leadership team needed to get vital information to staff, offer reassurance that a solution was being sought, and provide clear directives. Similarly, feedback from the clinical setting was critical to inform problem-solving and decision-making in the command room.

Although notifications were dispatched via multiple modes, there remained a risk that some staff did not receive the original message or subsequent status updates. Dynamic staff movement defined by multiple employee conditions (e.g., roles, hours, absence) and characteristic of large complex health settings, have implications for information sharing strategies (Australian Institute of Health & Welfare, 2015). The decision to operationalise the PA system was crucial, despite concerns regarding misapplication of equipment commissioned for emergency use, and perceived risk of provoking anxiety of patients. The action was not unprecedented; Coffey et al. (2016) reported making PA notifications during an unexpected computer hardware failure in a large US research hospital. During the current event, steps to mitigate patient anxiety included reassurance by staff as they interacted with patients and regular official update notices delivered with patients' meals. Interestingly, although communication using the PA system was effective, participants most strongly endorsed 'face-to-face' communication as it was direct, personally delivered, and reassuring.

Face-to-face communication and reciprocal flow of information between staff on the floor and the leadership team contributed to the sense of comradery expressed by participants who referenced the support, cooperation, and cohesion observed during the event. Many felt it noteworthy that hospital and IT executives walked through the hospital talking to staff and checking on their wellbeing. This corresponds to the insights gained from a 10-day system outage in a Canadian hospital, where the presence of the leadership team on the wards was acknowledged as important to staff morale (Minghella, 2013). Large health service institutions need policies for communication strategies and procedures relative to iEHR disruptions. In particular, to establish a mechanism of vertical communication that encourages participative involvement and supports judicious decision-making and staff cooperation within organisations (Bartels, Peters, de Jong, Pruyn, & van der Molen, 2010).

3.2. Teamwork

The process of safely restoring patients' medication records to the digital platform was conducted by multidisciplinary teams comprising nursing, pharmacy and medicine–quickly assembled and without familiarity and stability normally established in teams over time (Marks, Mathieu, & Zaccaro, 2001). Nevertheless, the colossal task was accomplished by the ad hoc teams during two days of intensive activity, comparably quicker than over a week as reported following a US hospital downtime event of 33 h~~ours~~ (Coffey et al., 2016). Attitudes critical to cooperative teamwork include a sense of competence to achieve team goals, trust in others to contribute, and a belief in the importance of teamwork (Salas, Shuffler, Thayer, Bedwell, & Lazzara, 2015). The success of the hastily-formed teams may be attributable to the collective strength of diverse professional roles and skills, key to solving complex real-world problems (Haynes et al., 2019) and motivated through sharing a meaningful goal (Van Der Vegt & Bunderson, 2005). Although hospitals are traditionally hierarchical (Taran, 2011), research consistently shows that multidisciplinary teams comprising many levels or specialties of health professionals are associated with improved patient outcomes and satisfaction (Epstein, 2014).

3.3. Contingency planning

A challenge identified was delay as ICT staff sought to accurately diagnose and treat the problem. This led to confusion and false-starts but ensured solutions were tested and safe for patients. Other hospitals reported an interim period of instability while the source of iEHR disruptions were identified and solutions provided (Coffey et al., 2016; Genes et al., 2013). In the current study, concurrent use of digital and paper records introduced the risk of missing or duplicated documentation, particularly in relation to medication. This prompted the decision to adopt a multidisciplinary checklist model for prescription, administration and documentation of medication during the recovery transition back to digital health records.

Contingency planning is essential in preparing for iEHR disruptions (Sittig, Ash et al., 2014) to minimise untested response strategies while ensuring health services (Jalali et al., 2018). Whether ICT disruptions are caused by software malfunction or cyberattack, policy, training, and decision-making frameworks are instrumental in strengthening hospital preparedness and safe and effective healthcare during an event. Evidence-based measures to prevent, reduce, or mitigate iEHR-related patient safety issues are provided by the Safety Assurance Factors for EHR Resilience (SAFER) guides, sponsored by the US Office of the National

Coordinator for Health Information Technology (Sittig, Ash et al., 2014). Recommendations include strengthening technological hardware and software, and developing policy and procedures to optimise safe use of electronic health records and guide activities in the event of the system being compromised (Sittig, Ash et al., 2014).

The SAFER Guides recommends the development of written procedures for substitute workflows to guide staff in how to function in a paper-based environment (Oral, Cullen, Diaz, Hod, & Kratz, 2015). Feedback resulting from this extended downtime revealed the high use of paper charts and assessment tools led to a shortage of supplies. In response, the hospital developed formal downtime procedures such as the transition checklist to ensure wards had adequate stationary supplies. Similarly, two US hospitals (Coffey et al., 2016; Genes et al., 2013) reported being ill-equipped in access to paper documents for use during extended downtime events. For example, forms stored on the web were poorly indexed and difficult to locate (Coffey et al., 2016). It is commonly recommended that health facilities ensure availability of paper forms in all patient care areas (Primeau, 2018). Coffey et al. (2016) reviewed and updated paper downtime forms and created a 'downtime toolkit' to be installed, maintained, and restocked by each individual area.

Participants expressed a need for more digital disruption training during business hours to improve familiarity in off-line operations. While planned downtimes were embedded in organisational policy and undertaken every three months (during the night to reduce disruption to the delivery of patient services), this approach may not have adequately prepared staff. Well-intentioned policies and procedures may inadvertently disrupt work patterns and relationships that underlie resilience to unexpected operational challenges. In this study, analysed participants interviews identified effective, emerging work patterns that may contribute to best practice to safely recover from unplanned downtime events and provide guidance to other health services (Hegde et al., 2020)(~~Hegde et al., 2019~~).

3.4. Study limitations

While many participants noted there was no patient harm during the downtime event, this study did not interview patients or analyse clinical data to assess the consequences of the digital disruption from patients' perspective. The adverse impact of unplanned downtime on patient safety and management of clinical services has been documented. A review of patient safety data from multiple US facilities for three years to 2016 identified 76 downtime-related incidents (Larsen et al., 2017). The majority were laboratory issues (49%), often resulting in specimens having to be redrawn and delays in reporting results (Larsen et al., 2017). Medication-related incidents, involving administration of the wrong dose/medication or incorrect ordering, was the second most common (14%). An Australian hospital study showed that even brief system outages can cause delays in pathology processes and impact on patient safety (Wang et al., 2016). Observation of emergency department activities during unexpected downtime events revealed increased patient length of stay (Genes et al., 2013; Wretborn et al., 2019), higher patient walk-out rate (Genes et al., 2013), and an increase in perceived workload by staff (Wretborn et al., 2019). Surgeries conducted during downtime were typically longer (Genes et al., 2013; Harrison et al., 2019).

4. C~~ONCLUSIONS~~onclusions

Analysis of nine interviews of clinicians across the care continuum identified that the magnitude and complexity of the problems due to iEHR disruption were unprecedented and unpredictable. Multiple layers of decision-making, proactive initiatives with keen focus on patient safety, and strong horizontal and vertical leadership were crucial elements in successful recovery and operational normalisation. The computer-assisted qualitative data analysis strategy enabled a reproducible, transparent, valid and rigorous approach to inform downtime preparedness for digital health services.

~~5Author C~~Author contributions

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in *Collegian.*

Funding

The Division of Surgery at the Princess Alexandra funded the professional transcription of interviews.

~~7Ethical S~~Ethical statement

Ethical approval was granted for this study. Following initial review by the health service Human Research Ethics Committee, the project was considered to be exempt from full ethical review (HREC/17/QPAH/451; HREC/17/QPAH/539).

Conflict of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

~~Uncited referencesComptroller & Auditor General (2017) and Sittig et al. (2014).~~Acknowledgements

We would like to thank the participants for their time and insights.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.colegn.2020.02.002.

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