

1 Imitating incidents: how simulation can improve safety investigation and
2 learning from adverse events

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1 **Summary Statement**

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3 One of the most fundamental principles of patient safety is to investigate and learn
4 from the past in order to improve the future. However, healthcare organisations can
5 find it challenging to develop the robust organizational processes and work practices
6 that are needed to rigorously investigate and learn from safety incidents. Key
7 challenges include difficulties developing specialist knowledge and expertise,
8 understanding complex incidents, coordinating collaborative action and positively
9 changing practice. These are the types of challenges that simulation is commonly
10 used to address. As such, this paper proposes that there are considerable
11 opportunities to integrate simulation more deeply and systematically into routine
12 efforts to investigate and learn from safety incidents. This paper explores how this
13 might be done by defining five key areas where simulation could be productively
14 integrated throughout the investigation and learning process, drawing on examples of
15 current practice and analogous applications in healthcare and other industries.

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1 Imitating incidents: how simulation can improve safety investigation and 2 learning from incidents

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4 When things go wrong in healthcare, and when patients are harmed, it is essential
5 that incidents are rigorously investigated so that systems and practices can be
6 improved and similar events avoided in future. The need to learn from incidents has
7 long been an organizing principle of patient safety improvement,^{1,2} but healthcare
8 organisations can find it challenging to develop the robust work practices and
9 organizational processes that are required to investigate and learn from serious
10 events.^{3,4,5,6,7} This can be a serious problem. Poor quality or haphazard approaches to
11 investigating and learning from incidents can have considerable and far-ranging
12 consequences. They can allow safety problems to persist, exposing future patients to
13 harm.^{8,9} They can prevent harmed patients and families from being provided the
14 truthful information they deserve.^{10,11,12} They can leave healthcare staff working in
15 suboptimal, frustrating and poorly designed healthcare systems.^{13,14} **And they can
16 result in the misidentification of causal factors, leading to organisational resources
17 being wasted on irrelevant or inappropriate issues.^{15,16}**

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19 Accordingly, a range of recent initiatives in healthcare systems around the world aim
20 to improve the quality, scope and impact of safety investigation in healthcare. This

1 includes a renewed focus on investigation methods that translate findings into
2 practical improvements¹⁷ and the establishment of national patient safety
3 investigation bodies that are modelled on well-established approaches in other
4 safety-critical industries.^{9,18,19} Simulation has long played a major role in efforts to
5 improve patient safety,^{20,21} and many of the challenges commonly associated with
6 investigating and learning from safety incidents are those that simulation is typically
7 used to address,²² such as developing practical expertise, exploring complex
8 scenarios, improving organizational processes and strengthening social relations.
9 This paper proposes that a closer and more systematic integration of simulation into
10 routine activities of safety investigation would provide healthcare systems with a
11 variety of opportunities to improve practices of investigation and enhance what
12 organizations learn from incidents. The paper aims to develop a broad framework for
13 understanding how simulation and investigation might be more systematically
14 integrated across the entire process of investigating and learning from incidents, and
15 to begin to map out a future vision for the rigorous application of simulation
16 techniques to incident investigation. To do this, the key challenges in current
17 approaches to investigating patient safety incidents are first described. **Then, the**
18 **paper defines five key strategies for using simulation that address each of these**
19 challenges and improve the practices of investigating and learning from incidents,

1 drawing on current practice and future potential strategies. The paper concludes by
2 reflecting on how this work may be taken forward.

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5 **Investigative challenges**

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7 The core purpose of safety investigation is to systematically understand the past in
8 order to improve the future.²³ Rigorous and routine safety investigation has been a
9 fundamental feature of other safety-critical industries for many years but remains a
10 relatively young discipline in healthcare—and may at times not even be recognised as
11 a formal discipline that depends on specialised skills, knowledge, methods and tools.
12 In aviation, for example, the history of formally investigating serious safety incidents
13 reaches back over a century and is underpinned by well-established professional
14 communities, institutional arrangements and sophisticated tools and methods.^{24,25,26}
15 Despite considerable effort over the past two decades, many healthcare systems have
16 yet to develop equivalent institutional arrangements and professional communities
17 that ensure safety incidents are routinely and robustly investigated and result in
18 rapid, widespread and sustainable improvements.^{27,28} The main challenges faced by
19 healthcare systems in investigating and learning from patient safety incidents are
20 fivefold, and each is at least partially addressable through simulation (Table 1).

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2 First, safety investigation is a challenging and specialist task that depends on the
3 work of expert safety investigators with highly specialised *knowledge and skills*.
4 These specialist skills of investigation are not typically widespread in healthcare.^{4,12}
5 Second, investigating and responding to a serious patient safety event typically
6 involves a range of organizations and professional groups working together. This
7 requires robust *organizational processes* including effective resourcing, coordination
8 and communication that are separated from any parallel activities concerning legal
9 liability and blame. It is not uncommon for these processes to become confused in
10 ways that undermine effective investigation and learning.^{3,13} Third, systematically
11 *analysing and addressing* the causes of patient safety issues can be deeply
12 problematic. Serious safety incidents are complex and usually result from myriad
13 interactions between human, technical, organizational and regulatory factors.²⁹
14 Solutions can be equally complex and moving from analysis to action remains a
15 persistent challenge.^{13,17} Fourth, it can be challenging to ensure that *lessons are*
16 *embedded* in practice and that the findings and recommendations from
17 investigations lead to material changes in practical work. Learning can only be said to
18 have occurred when knowledge, activities and technologies on the frontline of
19 healthcare are updated and improved.^{30,31} Fifth, one of the most difficult aspects of
20 learning from serious events is making sure that the lessons from investigations have

1 a *system-wide impact*, leading to improvements in safety across multiple
2 organizations. At core, investigation and learning are only successful if similar
3 serious events are avoided across a healthcare system, preventing other patients
4 being harmed in the same way.^{23,27}

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7 **Integrating simulation and safety investigation: five strategies**

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9 This paper proposes that deeply integrating simulation into the processes of
10 investigating and learning from serious safety incidents provides opportunities to
11 enhance the practices of safety investigation, develop more robust systems of analysis
12 and improvement, and more reliably spread and embed lessons across healthcare
13 systems. Each of the key challenges facing investigation and learning, described
14 above, can be addressed through the careful and systematic use of five interconnected
15 simulation strategies (Table 1), and each of these strategies are explored in turn
16 below. Here, simulation is defined broadly as any technique that can replace or
17 amplify real-world experiences for the purposes of reflective learning.³² This spans
18 role-play, table-top exercises, online or virtual reality simulations, task trainers and
19 fully immersive simulations using standardised patients and other actors. These
20 simulation strategies can support learning at multiple levels of a healthcare system,

1 from adaptation in individual skills and knowledge, to improvement in teamwork and
2 collaboration, to reform and redesign of organisational systems and processes.³¹

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4 << INSERT TABLE 1 AROUND HERE >>

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6 **Immersive investigator training**

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8 Investigating serious patient safety incidents requires safety investigators to reliably
9 apply expert knowledge and specialised skills to complex scenarios in which people
10 are distressed and information is often ambiguous and contested. The work of
11 investigators is highly varied, including interpreting clinical and organizational data;
12 analysing system design and human factors; sensitively interviewing harmed
13 patients, bereaved relatives and healthcare workers; and developing robust
14 improvement recommendations. This requires a mix of deep technical expertise and
15 practical skill. Immersive simulation-based training has long been used in other
16 safety-critical settings such as aviation, where investigators are able to undertake
17 multi-week simulated investigations as part of their training, from examining
18 wreckage sites to handling media interviews.³³ Simulation-based training represents
19 a key strategy for developing the practical skills and knowledge of safety

1 investigators,³⁴ and sensitising investigators to the biases that can adversely influence
2 investigations.³⁵

3

4 Some forms of table-top and online simulations are used in current investigation
5 training or safety improvement activities.^{36,37,38} However, there are significant
6 opportunities to more systematically implement immersive investigator training,
7 targeted at developing key competencies such as interviewing, evidence
8 identification, systems analysis and recommendation development. In more intensive
9 future forms, investigator training could take the form of simulating end-to-end
10 investigations spanning multiple days or weeks, enacting the entire trajectory of a
11 major investigation as a core component of investigator training. Simulations could
12 recreate the conditions, challenges and interactions necessary in real-world
13 investigation, beginning with the immediate aftermath of an incident, using actors to
14 allow investigators to interview patients, families and staff, and simulating an
15 examination of the incident setting, equipment, data and records. Simulation training
16 could then move to the work of analysing and interpreting data, including liaising
17 with stakeholders such as executives, regulators, coroners and media—played by
18 actors—completed by developing a final report and recommendations. Any of these
19 specific activities can be extracted as shorter task-oriented simulation scenarios, but
20 longitudinal, end-to-end simulations would allow investigators to learn how to both

1 apply and integrate the various technical and social skills, investigative techniques
2 and analysis methods required of them in high-fidelity simulations where there is no
3 risk of causing further emotional distress to patients, families or staff. This approach
4 would be analogous to the longitudinal immersive simulation training that is
5 increasingly being used to support effective transition of interns.³⁹

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8 **Improving investigative infrastructure**

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10 Patient safety incidents often result from a complex set of factors that span many
11 different parts of a variety of organizations across a healthcare system. These include
12 things like communication problems between ambulatory and secondary care,
13 oversights by accreditors or regulators, and poor design decisions by equipment
14 manufacturers. Investigating complex safety issues therefore requires a well-
15 developed investigative infrastructure of robust systems, protocols and processes that
16 allow investigations to effectively bring together and coordinate different participants
17 such as patients, managers, clinicians, subject matter experts and executives; support
18 efficient communication with all parties involved—especially patients and families;
19 and span different units, departments or organizations where necessary. This
20 investigative infrastructure can be challenging to develop in many healthcare

1 systems, particularly where it has emerged from prior administrative arrangements
2 focused on the management of complaints or medico-legal risks, where processes are
3 typically oriented to the resolution of individual cases rather than the examination of
4 broader system safety issues.

5
6 In future, the infrastructure that supports effective investigation—such as
7 communication channels, coordination mechanisms, information systems,
8 management structures, and related policies and protocols—could be routinely tested
9 and improved through different forms of simulation.²² Similar activities are already
10 used to explore and improve organisational processes related to patient safety. For
11 example, table-top group simulations of patient safety systems can be undertaken
12 with groups of healthcare executives to explore and reflect on safety strategies and
13 accountability structures in healthcare organisations,⁴⁰ or to simulate and explore the
14 relationship of local organisational activities with regional or national policy
15 requirements.⁴¹ Likewise, crisis management scenarios are commonly used to test
16 organisational policies, develop leadership capacity and strengthen communication
17 channels for dealing with organisation-wide crises.^{42,43} These existing approaches
18 could be extended and applied more directly to the organisational systems and
19 processes that are required to manage major incident investigations by, for example,
20 conducting annual in situ simulations of a major safety investigation to test and

1 improve the processes and protocols for investigating serious safety incidents. Ideally
2 these would be conducted in collaboration with other organizations in a local health
3 system and would include all key organizational participants—including executives
4 and senior clinicians—to test organizational processes and strengthen
5 communication channels across organizational boundaries—all while removed from
6 the stresses of an actual adverse event. However implemented, simulations could
7 target key competencies and organisational processes that include: initial response to
8 an incident; liaising with and supporting patients, families and staff; coordinating
9 with other healthcare organizations along the patient pathway; and communicating
10 with other actors such as regulators, coroners and the media.

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13 **Exploring causal factors and solutions**

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15 A fundamental purpose of investigating incidents is to understand the practical
16 problems that contribute to safety issues in healthcare, and to determine the changes
17 that can address those problems and make care safer. This process can be challenging
18 because incidents emerge from complex interactions between a wide variety of
19 human, technical and organizational factors that combine in unexpected ways in real-
20 world practice. Investigations need to grapple with the complexity of real-world

1 practice to understand the causes of incidents and to recommend appropriate
2 solutions. Simulation offers valuable ways of both retrospectively exploring the
3 underlying causes of incidents, as well as prospectively developing and testing
4 solutions. Formal methods of safety analysis that are used in different healthcare
5 settings can sometimes incorporate simulation techniques to recreate elements of an
6 event or context to better understand the causal factors involved, including
7 retrospective Root Cause Analysis,⁴ prospective Failure Mode and Effect Analysis²²
8 and other systems-oriented incident analysis methods.⁴⁴ Equally, simulation is used
9 to design, evaluate and test new healthcare products and services,⁴⁵ such as drug
10 packaging⁴⁶ or new hospital facilities.⁴⁷ Likewise, different forms of simulation—such
11 as virtual reconstructions or simulation centre re-enactments—are widely and
12 routinely used in safety-critical sectors such as aviation to recreate serious incidents
13 to understand how and why events unfolded.^{48,49}

14
15 These current applications of simulation indicate that there are considerable
16 opportunities to make more widespread use of simulation when investigating patient
17 safety incidents and developing subsequent improvements in healthcare. **One way**
18 **would be to routinize the use of in situ simulation to recreate incidents as part of all**
19 **major safety investigations.** This might involve bringing a multi-professional team
20 together in the original setting to re-enact a serious incident, allowing different

1 explanatory theories to be tested against real-world practice and providing
2 opportunities to uncover hidden human factors and systems issues. One well-
3 publicised example of this is the in situ simulation used to investigate the inadvertent
4 injection of Chlorhexidine during a lower limb angiogram that led to a patient's leg
5 being amputated, revealing a range of common human factors issues and potential
6 solutions.⁵⁰ Likewise, investigation processes that deeply integrate simulation
7 techniques into the development of safety improvements and recommendations
8 following serious incidents could help underpin more practical, robust and reliable
9 changes to organisational process and practice.⁵¹

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12 **Embedding lessons in practice**

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14 One of the key objectives of incident investigation is to improve safety by bringing
15 about changes in knowledge, skills, practice and process at the frontline of healthcare
16 delivery. This requires regularly developing safety recommendations and other
17 insights from investigations and translating them into practice. Simulation offers a
18 direct route for this. It is common practice for clinical simulation and team training
19 scenarios to be derived from past experiences and to draw inspiration from prior
20 events, both as a basis for improving clinical and teamwork skills^{20,52} and as a route

1 to making broader modifications and improvements to local work systems, cognitive
2 aids and care processes.⁵³ There have also been innovative attempts to more
3 systematically link healthcare simulation training programmes to the findings and
4 recommendations from recent local events and incident investigations.^{54,55} This
5 ongoing translation of the findings of past events into improved future practices is
6 widely instituted and supported in other safety-critical industries, where safety
7 investigation activities are closely linked to routine and regular simulation training
8 programmes.⁵⁶ In airlines, for example, information on recent incidents is regularly
9 shared with simulation training programmes to modify old scenarios or introduce
10 new ones.²³

11
12 Given the long experience in the healthcare simulation community of translating past
13 events into future learning opportunities, there are clearly significant opportunities
14 to use simulation to more systematically and routinely transform specific findings of
15 incident investigations into practical improvements in care delivery. As with the
16 other strategies defined here, fully realising these opportunities would require
17 significant resourcing and leadership commitment to both deeply integrate
18 simulation programmes into the routine delivery of healthcare, and to develop tight
19 linkages between those simulation programmes and patient safety analysis and
20 investigation teams. Examples of successfully integrating simulation education

1 programmes into the rapid design, development and implementation of new clinical
2 and organisational practices demonstrates the importance of building strong
3 relationships between simulation groups and other key patient safety and clinical
4 units across a healthcare system.⁵¹ More closely integrating safety investigation teams
5 with simulation programmes raise important practical questions. For instance,
6 patient safety investigation methods may need updating, to include a defined process
7 to identify issues suitable for rapid improvement through simulation-based training.
8 Equally, the outputs of investigations may need to be improved, to provide the level
9 of practical and contextual detail required to develop high-fidelity simulation
10 scenarios.⁵⁷ And simulation teams would need to become responsive and flexible to
11 quickly adapt scenarios and develop updates. All of this would require significant
12 organizational resourcing.

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15 **Vicariously probing systems**

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17 A persistent challenge in patient safety concerns how to spread lessons from
18 incidents to other organizations and across entire healthcare systems.²⁷ These
19 processes of vicarious learning—where organizations proactively learn from events
20 that occur elsewhere⁵⁸—can be challenging because the context in which an incident

1 originally occurred may differ in important ways from contexts in other settings. The
2 relevance and importance of lessons learnt in one organization may therefore not be
3 readily apparent in other settings. Likewise, safety improvements will typically need
4 to be modified and adapted to work elsewhere. As such, vicarious learning depends
5 on organizations actively using incidents that occur elsewhere as a trigger to test and
6 analyse their own systems and adapt safety recommendations to their local context.
7 Simulation provides a range of techniques to test and reflect on current work
8 practices and organisational processes, and is often used in healthcare to identify
9 hidden or latent safety risks in current clinical systems,^{59,60,61} or prepare for major
10 crises such as outbreaks of highly communicable diseases.⁵¹ ‘Systems-probing’ has
11 long been advocated as a key function of healthcare simulation,^{22,62} and other sectors
12 actively use systems-probing simulations to manage and regulate risk. For example,
13 the safety and soundness of financial institutions is regularly explored with simulated
14 virtual 'stress tests' that test the impact of extreme economic events.⁶³
15
16 Systems-probing simulations therefore represent a key mechanism to support
17 vicarious learning from serious safety incidents across healthcare systems. Routinely
18 attempting to recreate incidents that have occurred in other healthcare
19 organisations—such as a wrong-route high-risk medication incident in cancer units—
20 allows the safety of local systems to be examined. This is often done informally,

1 through storytelling or ‘trigger videos’ of serious incidents that prompt reflection on
2 and inquiry into local systems and practices.²² Anecdotally, high-profile and
3 emotionally engaging films that retell the story of serious incidents^{51,57} appear to have
4 triggered widespread reflection and change.⁶⁴ More resource intensive in situ
5 simulations of major events can provide a richer view of actual, rather than imagined,
6 work processes, and have been used to drive change in local systems and practices
7 such as relating to obstetric emergencies.⁵³ There are also opportunities for
8 regulators, accreditors and other system supervisors to more formally incorporate
9 systems-probing safety 'stress tests' in their assessment regimes. For example,
10 processes of hospital inspection or accreditation could routinely include a simulated
11 test based on serious incidents experienced elsewhere, such as a table-top simulation
12 of a major equipment or power failure, or the multi-organization coordination that is
13 required in rapidly diagnosing and treating a child seriously ill with sepsis.⁶⁵ If
14 resourced appropriately and integrated into routine practice, vicarious systems-
15 probing simulations offer one route to turning passive incident investigation reports
16 into active processes of vicarious learning that could help ensure lessons travel widely
17 around a healthcare system.

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1 **Conclusion: Simulating investigation and investigating** 2 **simulation**

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4 This paper proposes that deeper and more systematic integration between the field of
5 simulation and activities of safety investigation offers a broad range of opportunities
6 for enhancing how healthcare systems routinely understand and learn from safety
7 incidents. **Five key strategies are proposed to help healthcare systems** maximise what
8 is learnt from past incidents, and address some of the core challenges that healthcare
9 organisations commonly face in incident investigation (Table 1). These strategies
10 span the entire process of investigating and learning from incidents: improving
11 investigator training, strengthening organizational systems, supporting analysis
12 methods, embedding lessons in practice and widely sharing improvements. To date,
13 healthcare simulation techniques have been applied in each of these areas in some
14 form, and in some areas are well-advanced. By defining a framework of five key
15 strategies, this paper aims to provide a broader view of how simulation can be
16 applied in an integrated way to investigating and learning from patient safety
17 incidents, as well as to begin outlining a future vision of potential practice in each of
18 these areas as a spur for future research.

19

1 Developing this work further will require considerable effort, both in research and in
2 practice. The vision of deeply integrating simulation into the fabric of healthcare
3 delivery is a long-standing aspiration for many in the simulation community,^{22,32,51}
4 and the framework described here represents an elaboration of a small part of that.
5 As such, further integrating simulation into the routine activities of incident
6 investigation faces similar challenges. One of the main challenges concerns
7 organizational resourcing and capacity. Bringing more sophisticated forms of
8 simulation into routine investigative activities—such as in situ recreations of
9 incidents or longitudinal immersive education programmes for investigators—would
10 likely require significant investment, along with specialist expertise and technical
11 support that is not yet widely available. Likewise, simulation programmes and
12 organisational structures would likely need considerable redesign to support the
13 routine engagement of many different organizational participants in incident
14 simulations, from senior executives to frontline staff, and would need to be
15 appropriately resourced to respond rapidly and flexibly to the regular release of
16 investigation findings and recommendations. These all represent major
17 organizational challenges that would need ambitious and committed support from
18 healthcare leaders. The framework described here also points to a wide range of
19 important avenues for future research, which would require a broad programme of
20 work. In the broadest of terms, these questions concern the optimal design, purpose

1 and modality of simulation techniques that can support processes of investigating
2 and learning from past incidents at different levels of a healthcare system. Given the
3 long time periods that can unfold between implementing new simulation techniques
4 and resulting changes in organisational systems and processes, any programme of
5 research would need to develop careful evaluation strategies to examine both the
6 long-term impacts on safety performance and organisational design, as well as
7 shorter-term changes in practices and knowledge. Engaging with these issues in
8 research and practice, and more closely integrating simulation with investigation,
9 points to a variety of ways that healthcare can build a more robust, integrated and
10 system-wide approach to investigation and learning. It also offers rich opportunities
11 to further explore and expand the boundaries of healthcare simulation as a
12 fundamental safety improvement strategy.

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6 Investigation Branch.

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1 **References**

- 2 1. Kohn LT, Corrigan JM, Donaldson MS: *To err is human: Building a Safer*
3 *Health System*. Washington, DC, Institute of Medicine, 1999.

- 4 2. Department of Health: *An Organization with a Memory: Report of an Expert*
5 *Group on Learning from Adverse Events in the NHS Chaired by the Chief*
6 *Medical Officer*. London, Department of Health, 2000.

- 7 3. Macrae C: The Problem with Incident Reporting. *BMJ Qual Saf* 2016;
8 25(2):71-75.

- 9 4. Peerally MF, Carr S, Waring J, Dixon-Woods M: The problem with root cause
10 analysis. *BMJ Qual Saf*, Published Online First: 23 June 2016.
11 doi:10.1136/bmjqs-2016-005511

- 12 5. Francis R: *Independent Inquiry into Care Provided by Mid Staffordshire NHS*
13 *Foundation Trust January 2005–March 2009*. London, The Stationery Office,
14 2010.

- 15 6. Quality of Care Information Protection Act Review Committee: *QCIPA Review*

- 1 Committee Recommendations. Ontario, 2014.
- 2 7. Australian Commission on Safety and Quality in Health Care: Review of the
3 Department of Health and Human Services' management of a critical issue as
4 Djerriwarrh Health Services. Victoria, 2015.
- 5 8. Thomas M, Schultz TJ, Hannaford N, Runciman WB: Mapping the limits of
6 safety reporting systems in health care-what lessons can we actually learn.
7 *Med J Aust* 2011; 194(12):635-9.
- 8 9. Macrae C, Vincent C: Learning from failure: the need for independent safety
9 investigation in healthcare. *J R Soc Med* 2014; 107:439-43.
- 10 10. Titcombe J: Joshua's Story: Uncovering the Morecambe Bay NHS Scandal.
11 London, Anderson Wallace, 2015.
- 12 11. Zimmerman TM, Amori G: Including Patients in Root Cause and System
13 Failure Analysis: Legal and Psychological Implications. *J Healthc Risk Manag*
14 2015; 27(2):27-34.
- 15 12. Care Quality Commission: Learning from serious incidents in NHS acute
16 hospitals: A review of the quality of investigation reports. London, CQC, 2016.

- 1 13. Mitchell I, Schuster A, Smith K, Pronovost P, Wu A. Patient safety incident
2 reporting: a qualitative study of thoughts and perceptions of experts 15 years
3 after “ To Err is Human.” *BMJ Qual Saf* 2016; 25:92-99/
- 4 14. Berwick, D and the National Advisory Group on the Safety of Patients in
5 England: A Promise to Learn – A Commitment to Act. London, Department of
6 Health, 2013.
- 7 15. Turner B, Pidgeon N: Man-Made Disasters. Oxford, Butterworth-Heinemann,
8 1997.
- 9 16. Wildavsky A: Searching for Safety. Oxford, Transaction, 1988.
- 10 17. National Patient Safety Foundation: RCA2: Improving Root Cause Analyses
11 and Actions to Prevent Harm. Boston, MA, NPSF, 2016.
- 12 18. Healthcare Safety Investigation Branch Expert Advisory Group: Report of the
13 Expert Advisory Group: Healthcare Safety Investigation Branch. London,
14 Department of Health, 2016.
- 15 19. Norwegian Government: Act on the State Investigation Commission for the
16 Health and Care Services. Oslo, Norway, 2017.
- 17 20. Gaba DM, Howard SK, Fish KJ, Smith BE, Sowb YA: Simulation-based

- 1 training in anesthesia crisis resource management (ACRM): a decade of
2 experience. *Simul. Gaming* 2001; 32(2):175–193.
- 3 21. Schmidt E, Goldhaber-Fiebert SN, Ho LA, McDonald KM: Simulation
4 exercises as a patient safety strategy. *Ann. Intern. Med* 2013; 158(2):426-32.
- 5 22. Driver JE, Gaba DM, Lighthall GK: The benefits of using simulation in risk
6 management and patient safety. In B. Youngberg (Ed.), *Principes of Risk*
7 *Management and Patient Safety*. London, Jones and Bartlett 2011.
- 8 23. Macrae C, Vincent C: *Investigating for Improvement: Building a National*
9 *Safety Investigator for Healthcare*. London, Clinical Human Factors Group,
10 2017.
- 11 24. ATSB: *Analysis, Causality and Proof in Safety Investigations*. Canberra,
12 Australian Transport Safety Bureau, 2007.
- 13 25. Macrae C: *Close Calls: Managing Risk and Resilience in Airline Flight Safety*.
14 London, Palgrave, 2014
- 15 26. Woods DD, Dekker S, Cook R, Johannesen L, Sarter N: *Behind human error*,
16 2nd edition. Aldershot, Ashgate, 2010.
- 17 27. Donaldson L: When will health care pass the orange-wire test? *Lancet* 2004;

- 1 364:1567–8.
- 2 28.Trbovich P, Shojanian KG: Root-cause analysis: swatting at mosquitoes versus
3 draining the swamp. *BMJ Qual Saf* 2017, First Published Online
4 doi:10.1136/bmjqs-2016- 006229.
- 5 29.Reason J: *Managing the Risks of Organizational Accidents*. Aldershot,
6 Ashgate, 1997.
- 7 30.Sujan M: An organization without a memory: a qualitative study of hospital
8 staff perceptions on reporting and organizational learning for patient safety.
9 *Reliability Eng Syst Saf* 2015; 144:45–52.
- 10 31. Drupsteen L, Guldenmund FW: What Is Learning? A Review of the Safety
11 Literature to Define Learning from Incidents, Accidents and Disasters.
12 *Journal of Contingencies and Crisis Management* 2014; 22(2):81–96.
- 13 32. Gaba DM: The Future Vision of Simulation in Healthcare. *Simul Healthc*
14 2007; 2(2):126–135.
- 15 33. Cranfield Safety and Accident Investigation Centre: Fundamental of accident
16 investigation Web site.
17 <https://www.cranfield.ac.uk/~media/files/brochure/fundamentalsofaccident>
18 investigationweb.ashx

- 1 34. Saunders-Smiths GN, Schuurman MJ, Rans CD: Forensic Engineering:
2 Learning by Accident—Teaching Investigation Skills to Graduate Students
3 Using Real-life Accident Simulations. American Institute of Aeronautics and
4 Astronautics, 2015, <http://dx.doi.org/10.2514/6.2015-1516>
- 5 35. Woodcock K, Drury CG, Smiley A, Ma J: Using simulated investigations for
6 accident investigation studies. *Appl Ergon* 2005; 36:1–12.
- 7 36. Murphy M, Duff J, Whitney J, Canales B, Markham MJ, Close J:
8 Implementation of a mock root cause analysis to provide simulated patient
9 safety training. *BMJ Open Qual* 2017; 6:e000096.
- 10 37. Health Foundation: A year in an hour: Quality Improvement through
11 Interactive Simulations Web site.
12 [http://www.health.org.uk/programmes/evidence-practice/projects/year-](http://www.health.org.uk/programmes/evidence-practice/projects/year-hour-quality-improvement-through-interactive-simulations)
13 [hour-quality-improvement-through-interactive-simulations](http://www.health.org.uk/programmes/evidence-practice/projects/year-hour-quality-improvement-through-interactive-simulations)
- 14 38. Armstrong Institute for Patient Safety and Quality: Simu-Leader: Training in
15 leadership for patient safety and quality improvement. Web site.
16 [http://www.hopkinsmedicine.org/armstrong_institute/improvement_project](http://www.hopkinsmedicine.org/armstrong_institute/improvement_projects/simuleader.html)
17 [s/simuleader.html](http://www.hopkinsmedicine.org/armstrong_institute/improvement_projects/simuleader.html)
- 18 39. Laack TA, Newman JS, Goyal DG, Torsher LC: A 1-Week Simulated Internship

- 1 Course Helps Prepare Medical Students for Transition to Residency. *Simul*
2 *Healthc* 2010; 5(3):127–132.
- 3 40. Rosen MA, Goeschel CA, Che XX, Fawole JO, Rees D, Curran R: (2015).
4 Simulation in the Executive Suite. *Simul Healthc* 2015; 10(6):372–377.
- 5 41. Cohen D, Vlaev I, McMahon L, Harvey S, Mitchell A, Borovoi L, & Darzi A: The
6 Crucible simulation. *Health Care Manage Rev* 2017; 42(4):1–10.
- 7 42. Waller MJ, Lei Z, Pratten R: Focusing on Teams in Crisis Management
8 Education: An Integration and Simulation-Based Approach. *Acad Manage*
9 *Learn Educ* 2014; 13(2):208–221.
- 10 43. Newton, C: Protect the brand or die trying: inside a fake social media crisis.
11 The Verge Web site. [https://www.theverge.com/2015/3/20/8266539/sxsw-](https://www.theverge.com/2015/3/20/8266539/sxsw-2015-social-media-crisis-simulation-polpeo)
12 [2015-social-media-crisis-simulation-polpeo](https://www.theverge.com/2015/3/20/8266539/sxsw-2015-social-media-crisis-simulation-polpeo)
- 13 44. Pickup L, Lang A, Atkinson S, Sharples S: The dichotomy of the application of
14 a systems approach in UK healthcare the challenges and priorities for
15 implementation. *Ergonomics* 2017, Online first
16 <http://doi.org/10.1080/00140139.2017.1306632>
- 17 45. Health Quality Council of Alberta: Simulation based mock up evaluation
18 framework. Calgary, Health Quality Council of Alberta, 2016.

- 1 46. Garcia BH, Elenjord R, Bjornstad C, Halvorsen KH, Hortemo S, Madsen S:
2 Safety and efficiency of a new generic package labelling: a before and after
3 study in a simulated setting. *BMJ Qual Saf* 2017; 26:817-823.
- 4 47. Bender J, Shields R, Kennally K. Testing with simulation before a big move at
5 Women & Infants Hospital. *Med Health R I* 2010; 93:145-150.
- 6 48. National Transportation Safety Board: NTSB Accident animations Web site.
7 <https://www.nts.gov/Pages/animations.aspx>
- 8 49. Air Accidents Investigation Branch: Report on the accident to Bombardier
9 CL600-2B16 Series 604, N90AG at Birmingham International Airport 4
10 January 2002. Farnborough, Air Accidents Investigation Branch, 2004.
- 11 50. The Human Factor: Learning from Gina's Story. Web site.
12 <https://www.youtube.com/watch?v14IJfoLvLLoFo>
- 13 51. Phrampus PE, O'Donnell JM, Farkas D, Abernethy D, Brownlee K, Dongilli T,
14 Martin S: Rapid Development and Deployment of Ebola Readiness Training
15 Across an Academic Health System. *Simul Healthc* 2016; 11(2):82-88.
- 16 52. Gaba DG, Fish KJ, Howard SK, Burden AR: Crisis Management in
17 Anaesthesiology. London, Elsevier Saunders, 2014.
- 18 53. Macrae C, Draycott D: Delivering high reliability in maternity care: In situ

- 1 simulation as a source of organizational resilience. *Safety Science* 2016,
2 Published Online First <http://dx.doi.org/10.1016/j.ssci.2016.10.019>
- 3 54. Peerally MF, Fores M, Powell R, Durbridge M, Carr S: Implementing Themes
4 From Serious Incidents Into Simulation Training For Junior Doctors. *BMJ*
5 *Simulation and Technology Enhanced Learning* 2014, 1(Suppl 1), A22-A22.
- 6 55. Austin N, Goldhaber-Fiebert S, Daniels K, Arafah J, Grenon V, Welle D,
7 Lipman S: Building Comprehensive Strategies for Obstetric Safety. *Anesth*
8 *Analg* 2016; 123(5):1181–1190.
- 9 56. Civil Aviation Authority: Follow-up Action on Occurrence Report: Accident to
10 Boeing 747-436 G-BNLL. Gatwick, Civil Aviation Authority Safety Regulation
11 Group, 2015.
- 12 57. Simpect: The Elaine Bromiley Case Web site. <https://vimeo.com/103516601>
- 13 58. Denrell J: Vicarious learning, undersampling of failure, and the myths of
14 management. *Organization Science* 2003; 14(3):227-243.
- 15 59. Auerbach M, Kessler DO, Patterson M: The use of in situ simulation to detect
16 latent safety threats in paediatrics: a cross-sectional survey. *BMJ Simul.*
17 *Technol. Enhanced Learning* 2015; 1:77–82.

- 1 60. Patterson MD, Geis GL, Falcone RA, LeMaster T, Wears RL: In situ
2 simulation: detection of safety threats and teamwork training in a high risk
3 emergency department. *BMJ Qual Saf* 2013; 22(6):468–477.
- 4 61. Ventre KM, Barry JS, Davis D, Baiamonte VL, Wentworth AC, Pietras M:
5 Using in situ simulation to evaluate operational readiness of a children's
6 hospital-based obstetrics unit. *Simul Healthc* 2014; 9(2):102–111.
- 7 62. Hamman WR, Beaudin-Seiler BM, Beaubien JM, Gullickson AM, Gross AC,
8 Orizondo-Korotko K: Using in situ simulation to identify and resolve latent
9 environmental threats to patient safety: case study involving a labor and
10 delivery ward. *J Patient Saf* 2009; 5(3):184–187.
- 11 63. Bank of England: The Bank of England's approach to stress testing the UK
12 banking system. London, The Bank of England, 2017.
- 13 64. Syed M: *Black Box Thinking: The Surprising Truth About Success*. London,
14 John Murray, 2015.
- 15 65. Parliamentary and Health Service Ombudsman: *Learning from mistakes: An*
16 investigation report by the Parliamentary and Health Service Ombudsman
17 into how the NHS failed to properly investigate the death of a three-year old
18 child. London, PHSO, 2016.

