

Grand Rounds

‘When Right could be so Wrong’. Laterality Errors in Healthcare

Gerard J Gormley¹, Martin Dempster² Richard Corry³, Carl Brennan^{1, 4}

Accepted: 12th August 2017

Provenance: Invited review

‘I’m afraid I’ve got some bad news for you.’

He looked questionably at me.

‘And what’s that, Mr Marsh?’

‘I’m terribly sorry but I’ve gone and operated on the wrong side,’ I said.

He looked at me in silence...¹

INTRODUCTION

Distinguishing *right* from *left* can be challenging. During basic clinical training, we grappled with distinguishing *superior* from *inferior*, *proximal* from *distal*, *medial* from *lateral* but did you ever consider that some individuals may have had difficulty in telling *right* from *left*? We make right / left (RL) decisions on an everyday basis. Whether providing someone with travel directions or taking a car journey - laterality decisions are unavoidable. For many, discriminating right from left is an automatic process; an unconscious competency. However for a significant proportion of our population, distinguishing right from left is a complex task that requires conscious thought and effort.² Regardless of our ability to discriminate right from left, all of us at some stage can get it wrong – *to err is human*.³



Fig 1. Which side is the arrow on?

In many situations RL errors may lead to only minor consequences - such as providing the wrong travel direction. However in industries such as healthcare and aviation - RL errors can lead to significant harm.^{4,6} Interestingly it has been proposed that a laterality misjudgment may have been a contributory factor in the sinking of the Titanic “*He turned the ship right instead of left and, even though he was almost immediately told to correct it, it was too late and the side of the starboard bow was ripped out by the iceberg*”.⁷

In this article, we will review some of the science behind RL discrimination and how this applies to healthcare. We will also consider some measures to prevent such laterality errors occurring.

SPATIAL AWARENESS AND RIGHT LEFT DISCRIMINATION

The neuropsychological process underlying RL discrimination is complex.⁸ Despite an increasing evidence base - much remains unknown. We will provide a brief overview of some of the neuropsychological processing.

Spatial awareness considers an individual’s ability to maintain body orientation in relation to their surrounding environment⁹ – whether *front* or *back*, *up* or *down*, or *left* or *right*. *Egocentric* orientation considers direction in relation to one’s own body (e.g. either your right or left hand) and *extra-egocentric* orientation applies to direction in your setting (e.g. the left or right hand of the patient sitting in front of you).¹⁰ Research would suggest that, despite being a fundamental task, not everyone has the same spatial orientation capabilities.¹⁰ In terms of directions of spatial orientation, an individual will find more challenge in distinguishing *right* from *left* than *above* from *below* or *front* from *behind*.¹¹

Our ability to differentiate left from right in ourselves (*i.e.*

1. Centre for Medical Education, Queen’s University Belfast, Northern Ireland. 2. School of Psychology, Queen’s University Belfast, Northern Ireland 3. South Eastern Health and Social Care Trust, Northern Ireland. 4. Northern Ireland Medical and Dental Training Agency, Belfast, Northern Ireland.

g.gormley@qub.ac.uk

Correspondence: Dr Gerry Gormley

in an egocentric context) begins in early childhood.¹² By the age of 11 years, 50% of children can correctly differentiate left from right in others (i.e. in an extra-egocentric context). When distinguishing right from left, many higher cerebral functions are recruited including language (both receptive and expressive), memory, visuospatial processing and integration of sensory information such as visual stimulus.¹¹ In addition, *mental-rotation* is often required in distinguishing right from left (i.e. when two individuals are facing each other - their *right* side is directly opposite your *left* side). This *mental-rotation* function is thought to originate from the brain's fronto-parietal region.¹¹

Many have theorised why some individuals are more prone to confusing right from left. One theory relates to the association between cerebral hemispherical asymmetry and increased RL discrimination ability: a greater degree of cerebral hemispherical asymmetry has been linked to an improved ability in RL discrimination.¹² Schizophrenia has also been linked with cerebral hemispherical asymmetry and researchers have studied individuals with schizophrenia (and dyslexia) with the aim to identify specific genes that may be involved in handedness.¹³ Although a number of such genes were identified, it is felt likely that such a complex process is polygenic.¹³

Gender has also been investigated as a factor associated with RL discrimination ability. Though the evidence is not conclusive, males would appear to show a greater RL discrimination capability compared to females.¹¹ Such a finding could be explained by the fact that males tend to exhibit a greater degree of cerebral hemispherical asymmetry and visuospatial function.¹¹

There is no systematic evidence to indicate that handedness is associated with RL discrimination ability. Whilst some studies have reported that being right-handed is associated with greater RL discrimination ability, other studies have reported no difference.^{2,14}

WRONG SIDED ERRORS IN HEALTHCARE

Unfortunately, wrong-sided errors occur in healthcare. Laterality misjudgments represent some of the most catastrophic errors in medicine.^{4,15} If a body part has a bilateral representation there is an inherent risk of performing surgery or procedure on the incorrect side of the body. Very few surgical specialties escape the potential risk of wrong-sided events occurring.⁴ Efforts by many organisations such as the National Patient Safety Agency and The Joint Commission have reduced such 'never events' – but they continue to occur.^{16,17} Last year, there were 179 wrong-site surgeries reported to Strategic Health Authorities in England and many of these involved RL disparity errors.¹⁸

Surgical specialties, of course, are not the only clinical specialty where RL errors can occur. Other reported events include eye injections, nerve blocks, radiotherapy and thoracentesis.^{4,18,19}



Fig 2. Can you spot the error?

Using a root-cause analytical approach, Millar *et al* quantified and explored wrong-sided thoracentesis.¹⁹ They concluded that such errors are frequently multifactorial in origin with human error as a common factor.

They reported that the majority of events occurred on the patient's *right-side* (i.e. where the thoracenteses should have occurred on the patient's *left-side*). We theorise that right-handed individuals (i.e. the commonest form of handedness – c.90% of the population) tend to prefer performance to their right-side or their 'fluent side'. When making a RL decision in clinical practice (which is often subject to time pressures and interruptions) clinicians may therefore display laterality by subconsciously favouring their dominant side (e.g. their right-side) regardless of the actual side of the pleural effusion (e.g. the left-side).

Another common source of non-operative RL errors concerns requests for radiological investigations. The next time you are speaking to a radiographer, be sure to ask them how many times they have received requests to image the wrong side of a patient's body!

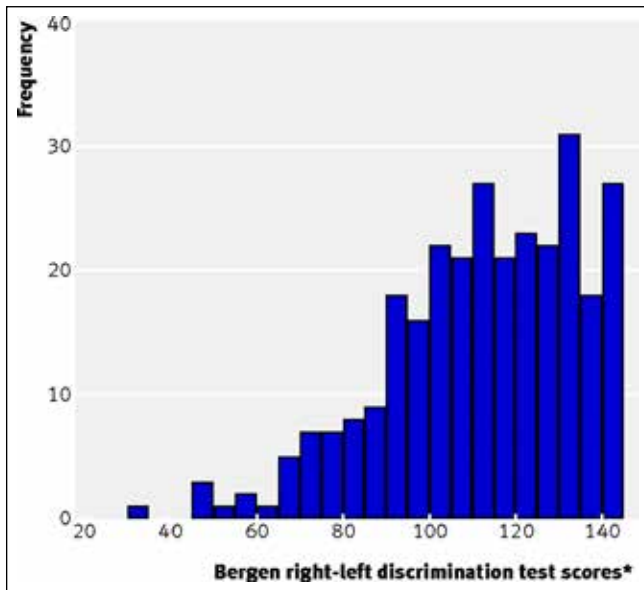
MEDICAL STUDENTS' ABILITY TO DISCRIMINATE RIGHT FROM LEFT

Very few studies have considered RL discrimination ability in healthcare professionals. In one study, a cohort of 290 medical students had their RL discrimination ability objectively measured using a psychometric test called the Bergen Right Left Discrimination Test (BRLDT).²⁰ Results of this study revealed that medical students displayed a range of ability in discriminating right from left. The higher the BRLDT score the better ability to discriminate right from left.

In this study, male students out-performed female students in RL discrimination but handedness did not appear to have any bearing on BRLDT test performance.

In terms of orientation, the greatest challenge for medical students seemed to involve mental rotation where they had to discriminate right from left when directly facing an individual – i.e. the commonest orientation in healthcare when a doctor





Participants' scores on the Bergen right-left discrimination test. *Scale of 0-144

Fig 3. Range of medical student's scores in the Bergen Right Left Discrimination Test²²

faces their patient (or viewing a standardised radiograph image). Interestingly, those students considering a career in surgery, compared to a career in GP or medicine, were more likely to have a greater ability at RL discrimination.²⁰

WHAT STRATEGIES CAN INDIVIDUALS USE TO ENHANCE RL DISCRIMINATING ABILITY?

When objectively measured, individuals vary in their ability to correctly discriminate right from left^{11,20} so that some are more prone to making RL errors. Can individuals judge their own RL discrimination ability? Evidence would suggest that individuals *perceived* RL discriminatory ability is significantly associated with their *objective* ability in distinguishing right from left.²⁰ However this is by no means an infallible assessment. Many individuals with difficulty differentiating right from left use a diverse range of assistive strategies and techniques.²⁰ Table 1 lists some of the various discriminatory strategies and techniques. One of the commonest techniques is demonstrated in figure 4. Extending the left thumb at a right angle to the outstretched index finger forms the letter 'L' to identify the left hand and side.

TABLE 1.

Range of 'techniques' that individuals use to aid their discriminating of right from left.²⁰

Discriminatory technique category	Example
Relates to a physical activity	'Right hand used to strum a guitar'
Relates to a unilateral body feature	'BCG scar on my right side'
Relates to a unilateral dress or accessory feature	'Wear my watch on my left side'
Use of word association	'Write with my right hand'

Do these techniques enhance an individual's ability to discriminate right from left? Evidence would suggest that despite using such techniques, individuals are still challenged in correctly discriminating right from left.²⁰ What remains unknown however is whether individuals can be trained to improve their RL discrimination ability.



Fig 4. A commonly used technique to aid the discrimination of right from left. By placing the index finger and thumb at right angles – the letter 'L' is made on the 'Left' side.

REDUCING RIGHT/LEFT ERRORS IN HEALTHCARE

Adverse events can arise in clinical practice when errors and latent conditions become aligned.²¹ In a complex system such as healthcare, adverse patient events are often multi-factorial but one common recurring cause is human error.²¹ We will now consider some approaches that aim to reduce wrong-side errors occurring – these incorporate individual, system and cultural strategies.

LEARNING FROM THE "HIGH-RELIABILITY" INDUSTRIES

In recent years, healthcare organisations have been increasingly looking to other (so-called "high-reliability") industries such as commercial aviation and nuclear power²² for learning in error-prevention strategies. For several decades, such industries have shown incremental improvement in operating safety and reliability by embracing a universal truth for human operators – to err is human³ In "high-reliability" industries, systems of working for human operators are relentlessly reviewed and redesigned to anticipate, prevent and mitigate for the *absolute certainty of human error*. Healthcare professions, in contrast, have been slow to accept this truth and have lost ground. In a world that increasingly expects error-free healthcare, we are now playing catch-up.

The aviation industry, following root-cause-analysis of a number of high-profile air disasters in the 1970s, began to appreciate the role of human error in airplane crashes.²³ The predominant failure was increasingly identified as dysfunction of the human teams managing the crisis rather than technical aircraft failure per se. Recurrent team failures included a breakdown in key skills such as leadership, situation



awareness, decision-making and interpersonal communication – such skills were termed *Non-Technical Skills* (NTS).²⁴ NTS can be defined as the ‘cognitive, social and personal resource skills that complement technical skills and contribute to safe and efficient task performance’.²⁴ In 1981, United Airlines was the first airline to commence training for flight staff in NTS and the training was called *Cockpit Resource Management* (CRM)^{25,26} – by the mid-1990s, CRM had become *Crew Resource Management* (to include cabin crew) and it was a global standard across the industry.

The healthcare industry is increasingly realising the importance of NTS, in complementing clinical and technical expertise. In 2003 psychologists, in conjunction with clinical anaesthetists, developed a taxonomy to describe the NTS relevant to safe and effective anaesthetic practice called the ANTS (Anaesthetists’ Non-Technical Skills) Framework.²⁵ This framework was designed to help anaesthetists recognise and assess the non-technical performance of themselves and others. Training courses to coach anaesthetic NTS, often employing simulation-based education (SBE), are now delivered throughout the United Kingdom and Ireland. Similar taxonomies have subsequently been developed for surgeons (Non-Technical Skills for Surgeons – NOTSS)²⁷ and scrub practitioners (Scrub Practitioners’ List of Intra-operative Non-Technical Skills - SPLINTS).²⁸

So how might a high-reliability industry tackle the problem of RL disparity? The science of *Human Factors* would suggest a number of strategies to prevent RL errors including:²⁹

- Education regarding risk awareness and meta-cognition
- Use of Standard Operating Procedure (SOP) & Checklists
- Use of technology
- Training to encourage effective team-functioning

EDUCATION ON RL DISPARITY

The first step in addressing any error is to increase awareness amongst operators of the risk of the error and potential consequences. Wrong-sided errors continue to occur and these errors can be devastating for both the patient and the *second victims*, namely the healthcare professionals involved.³⁰ Table 2 lists some of the factors which may potentially contribute to RL errors (adapted and modified from Pandit et al, 2017)³¹

The term *metacognition* is defined as an “awareness and understanding of one’s own thought processes” and higher order thinking skills. One of the main purposes of this article is to foster metacognition and self-awareness amongst practitioners that:

- RL discrimination ability is not reliably automatic or intuitive for many individuals
- RL decisions are frequently critical
- RL decisions should be afforded appropriate conscious effort and diligence, and should be actively processed through *working memory*

TABLE 2.

Categorised factors that may lead to right left errors in healthcare

Operator factors	<ul style="list-style-type: none"> • High pressured environment • Stress and time pressure • Fatigue and/or hunger • Novice operator or procedural uncertainty • Poor handover or change of staff mid-procedure • Poor record-keeping or inappropriate use of abbreviations • Interpersonal difficulties and authority gradients
Patient factors	<ul style="list-style-type: none"> • Patient sedation or confusion • Language or communication difficulties • Similar patient names • Bilateral pathology
Procedural factors	<ul style="list-style-type: none"> • Distractions and background noise • Excessive team numbers • Checking failure • Change in patient position • ‘Leading’ environment layout • Side marking incorrect, erased, covered or transferred

WORKING MEMORY

The Multi-Store Theory of Memory³² would suggest that there are three states of memory; namely *sensory*, *short-term* and *long-term* stores. The short-term memory is also referred to as the *working memory* and, in computing parlance, can be likened to an individual’s processor unit or home screen. The working memory also controls an individual’s conscious *awareness* and conscious thoughts.

The reality of the working memory is that it is capacity-limited and that active short-term memories are fragile and easily displaced or forgotten. Conscious thinking is also most effortful and to prevent mental overload, tends to be the least-preferred option particularly when busy. We can often function quite efficiently and effortlessly on an intuitive ‘auto-pilot’ setting. Although, undeniably efficient, such intuitive performance unfortunately represents a trade-off against thoroughness and accuracy (The Efficiency-Thoroughness Trade-Off).³³ Ability and reliability in RL discrimination varies between individuals and for some, RL decisions cannot be safely trusted to automatic performance. The danger in RL decisions therefore comes from situations where we fail to engage our working memory and commit such decisions to an unconscious process. In turn, anything that impacts upon the working memory will jeopardise RL discrimination and make errors more likely.

The working memory is vulnerable to many potential threats such as acute stress, time-pressure, fatigue, distractions, emotional extremes and intoxication to name a few.



DON'T DISTRACT ME!

Clinical tasks often occur in busy and challenging working environments.³⁴ From the ambient noise of telephones and monitors, to verbal interruptions and competing demands, such tasks are often nested in complex environmental dynamics. Distractions place an additional burden on working memory and jeopardise conscious RL discrimination. Evidence supports the theory that interruptions and distractions impact on an individual's ability to discriminate right from left.³⁴ In a situation where an individual's attention is divided between performing a task (such as discriminating right from left) and facing a distraction it is not surprising that the task may suffer.

Educational and organisational frameworks in healthcare need to recognise the importance of human factors in our challenging working environments. When making critical clinical decisions, such as marking a limb or performing a unilateral procedure, minimising interruptions and distractions is desirable. In response to a number of distraction-related air disasters, the Federal Aviation Authority enacted “The Sterile Cockpit” rule in 1981 – this rule dictates that flight crews must refrain from all ‘non-essential conversation’, to minimise unnecessary distractions, during all critical phases of flight (such as during turbulence or when plane altitude < 10,000 feet).³⁵ A similar “silent theatre” procedure has been adopted in some operating theatres to minimise distractions during the critical phases of a surgical operation. Those individuals who are prone to confusing right from left are likely to benefit from similar initiatives.

Design of our clinical environments can also have an impact on human factors. In terms of socio-materialism (i.e. how material objects interact with our socio-function and dynamics) there is increasing use of physical spaces known as ‘distraction free zones / quiet areas’.³⁶ Such areas signal to others that an individual is making an important decision (for example prescribing in a neonatal Intensive Care Unit). Such *socio-material* interventions may provide a safe sanctuary for those challenged in making RL decisions.

HUMAN SUGGESTIBILITY

Practitioners favour laterality procedures that play to their dominant side. The majority of individuals are right-handed so this would suggest that an RL error is more likely to occur in procedures that favour a left-handed approach. Such an unconscious drift may also be encouraged by other factors that play to human suggestibility. Examples of this would be where the practitioner anchors to an incorrect handover of laterality or where the procedural environment is set-up in such a way that subconsciously guides the unwary professional to the incorrect side. In the latter, such misleading cues can be very subtle where the practitioner is drawn, for example, to the side which is nearest, most spacious, uncovered, undraped or better illuminated, or when the room appears set-up to allude to a particular side. An example of this would be where the furniture, such as a procedure trolley or ultrasound machine, can seemingly act as an obstacle to one side and a misleading signpost to the other.

USE OF STANDARD OPERATING PROCEDURE (SOP) & CHECKLISTS

Another safety strategy employed to great effect by high-reliability industries is the formal Standard Operating Procedure, often used in conjunction with checklists. Assuming good design, an SOP is inherently safe by eliminating variation and confusion, and promoting predictability and consistency of performance.

In an attempt to prevent wrong-site procedures in healthcare, a number of SOPs have been recommended or mandated within the NHS. Some examples for the operating theatre include the Surgical Safety Checklist,³⁷ ‘Stop before you block’ initiative for unilateral nerve blocks³⁸ and skin-marking policies prior to surgery. Given that RL errors are not restricted to operating theatres, SOPs are also increasingly available for unilateral non-surgical procedures and are already commonplace in procedures such as thoracentesis³⁹ and eye injections.⁴⁰

Formal SOPs prevent and trap RL errors by a number of means:

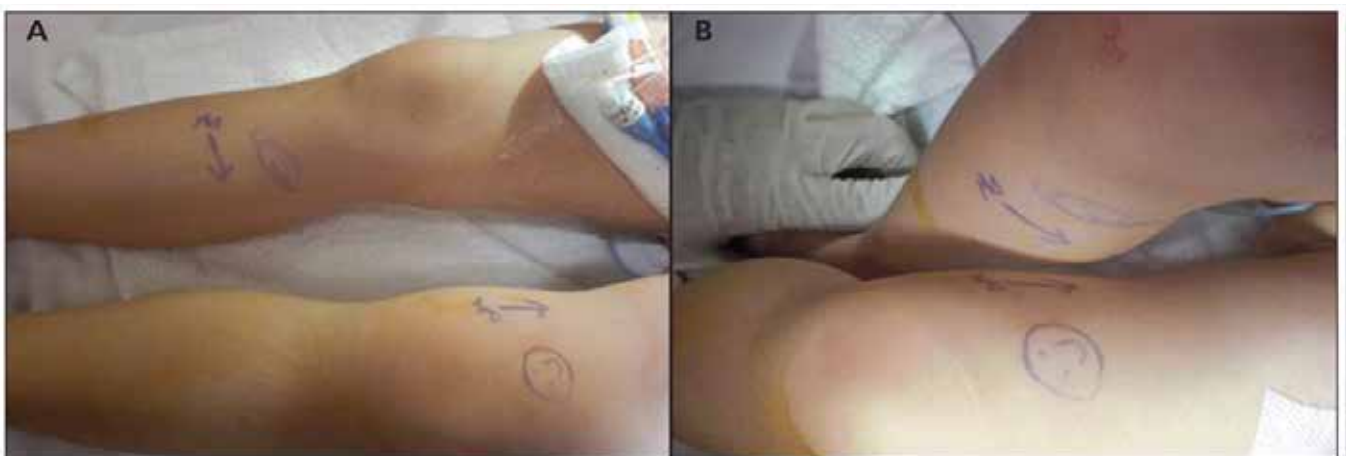


Fig 5. A cautionary case where a child's leg was marked ‘No’ for surgery but the ink transferred to the other leg when the legs touched each other. Dominique MA Knight and John H Wedge *CMAJ* 2010;182:E799. Used by kind permission of the Canadian Medical Association.

- Command a ‘time-out’ or ‘pausing-practice’ prior to the procedure to force engagement of conscious thought in relation to correct side and site
- Seek to promote a distraction-free environment
- Recruit the team to ‘cross-check’ RL decision and reach collaborative consensus
- Create an opportunity for challenge from patient or other staff

The World Health Organisation launched a Surgical Safety Checklist as part of a “Safe Surgery Saves Lives” Initiative in 2008.³⁷ The intention of the checklist is to promote team-functioning and prevent surgical ‘never events’ such as wrong-site surgery and retained foreign objects. At three points in any operation, the theatre team are obliged to stop and reevaluate against critical errors – the focus of two of these checks is to confirm that the imminent operation is progressing to the correct site and side. Whilst this worldwide initiative has saved countless lives globally, ‘never events’ such as wrong-site surgery unfortunately continue to occur.^{4,18} More research is needed to understand why errors still occur despite the use of safety checklists, particularly regarding the socio-cultural nuances of checklist practices.⁴¹

USE OF TECHNOLOGY

Technology and other innovations are increasingly employed to provide additional layers of protection and safety in healthcare. One such example in relation to wrong-sided errors is the recommendation that thoracenteses should be performed under direct ultrasound guidance³⁹ – the clinician must thereby objectively confirm the correct side by direct visualisation of the underlying pathology (e.g. a pleural effusion) at the time of the procedure. In human factors parlance, the ultrasound technology in this example acts as a *constraint* - a constraint can be defined as “the state of being checked, restricted, or compelled to avoid or perform some action”.²⁹

Laterality errors, though relatively infrequent, can also occur with radiological imaging and the reporting of such images⁴². The risk of potential patient harm from such errors can be significant. In recent years, computer software has been developed to flag-up image reports where there appears to be a RL conflict.⁴²

TRAINING TO ENCOURAGE EFFECTIVE TEAM-FUNCTIONING

In January 2000, a 70 year-old gentleman named Graham Reeves, underwent a left nephrectomy at the Prince Philip Hospital in Llanelli, Wales.^{43,44} It was only upon completion of the operation that the theatre team, with one exception, realised that Mr Reeves had undergone wrong-site surgery and that the ‘good’ left kidney had been accidentally removed in error. Mr Reeves, despite a subsequent salvage operation and treatment with haemo-dialysis, died five weeks later. The one exception in the theatre team that day was a medical

student – she had realised the error from a review of the imaging but had been unable to successfully challenge the surgical team as to their impending blunder. Mr Reeves was a victim of an RL error because of an administrative error which had caused the wrong side of operation to be listed on the operating schedule – he also fell foul of an authority gradient.^{3,44}

Authority gradients represent power-differentials whereby an individual’s actual or perceived status will rank them within a power-hierarchy or ‘pecking order’. Problems occur where authority gradients are steep because the power gap becomes a block to communication and challenge for lower-status individuals. Within the operating theatre, for example, surgeons tend to occupy top-status. In the case of Mr Reeves, the authority gradients on that day were simply too insurmountable for the young medical student and the consequences were disastrous.⁴⁵ Perhaps, through education, training to empower students and staff may be a worthy endeavor?

By the late 1970s, the aviation industry was increasingly aware that authority gradients were ‘costing’ the industry several planes each year. They realised that the solutions for success in an aviation crisis were much more likely to come from the team rather than from the top-dog captain whose brain was failing from mental overload. The prevailing culture, at that time, of a steep flight-deck hierarchy was killing off the team. The answer for regulators was to demand flatter authority gradients amongst flight-staff whereby, for instance, formal challenge of a senior was to be both permitted and expected. Such a change in culture, along with other improvements in flight team performance, was the principal focus of CRM training.²⁶

It is a reality that *competent individuals* do not necessarily make *competent teams*. In healthcare, one of the increasingly used resources for coaching team-skills and covering the principles of CRM is Simulation-Based Education (SBE). In SBE, a healthcare team can be safely exposed to a crisis scenario and their subsequent crisis-behaviours and team performance unpicked and critiqued during the formal debrief. Interprofessional-based education, to mimic real-life healthcare teams, is desirable for achieving both fidelity and collaborative competency. More training to improve team dynamics and performance, akin to CRM, can only help to prevent and capture errors such as RL disparity and wrong-site procedures.

CONCLUSION

In recent times significant inroads have been made in reducing wrong-sided errors – however we should continue to strive and make such *never-events* truly *never* events. Reducing laterality errors requires a deeper understanding of human behaviors and their complex interplay with working environments, teams, systems and organisations. According to Greek mythology, Ariadne helped Theseus navigate Minotaur’s labyrinth by providing him with a ball of thread



to guide his way out. Using this metaphor, applying human factors knowledge (such as difficulty in RL discrimination) into the milieu of clinical practice, could act as the *thread* to help guide health professionals in minimising patient harm through error. To err is human and it is no longer *right* to be *left* in the wrong.

CONTRIBUTORS STATEMENT

GG and CB contributed to the conception of this paper. All authors contributed to the drafting, critical revision and final approval of the final manuscript for publication. GJG is the guarantor.

FUNDING STATEMENT

No funding for writing this article

DECLARATION OF COMPETING INTERESTS

None declared

REFERENCES

- Marsh H. Admissions: a life in brain surgery. London: Weidenfeld & Nicolson; 2017. p. 226.
- Ofte SH. Right–left discrimination: effects of handedness and educational background. *Scand J Psychol.* 2002;**43**(3):213-9.
- Kohn LT, Corrigan JM, Donaldson MS, Institute of Medicine (US). Committee on Quality of Health Care in America. To err is human: building a safer health system. Washington (DC): National Academy Press (US); 2000.
- Neily J, Mills PD, Eldridge N, Dunn EJ, Samples C, Turner JR, *et al.* Incorrect surgical procedures within and outside of the operating room. *Arch Surg.* 2009;**144**(11):1028-34.
- Aviation Occurrence Report. ASC AOR 16 06 001. Loss of control and crashed into Keelung river three nautical miles east of Songshan airport: 4 February, 2015. TransAsia Airways Flight GE235 ATR72-212A. New Taipei City: Taiwan. Aviation Safety Council; 2015 Available from: https://www.asc.gov.tw/upload/acd_att/ASC-AOR-16-06-001%20EN.pdf. Last accessed October 2017.
- Helmreich RL. On error management: lessons from aviation. *BMJ.* 2000;**320**(7237):781-5.
- Alleyne R. Titanic sunk by steering blunder, new book claims. The Telegraph. 2010 Sep 14. Available from: <http://www.telegraph.co.uk/culture/books/booknews/8016752/Titanic-sunk-by-steering-blunder-new-book-claims.html>. Last accessed October 2017.
- Hjelmervik H, Westerhausen R, Hirnstein M, Specht K, Hausmann M. The neural correlates of sex differences in left-right confusion. *Neuroimage.* 2015;**113**:196-206.
- Federal Aviation Administration. Pilots: Pilot Safety: Aeromedical Safety Brochures: Spatial disorientation. Washington: United States Department of Transportation: Federal Aviation Administration; 2017. Available from: <https://www.faa.gov/pilots/safety/pilotsafetybrochures/media/SpatialID.pdf>. Last accessed October 2017.
- Auer T, Schwarcz A, Aradi M, Kalmar Z, Pendleton C, Janszky I, *et al.* Right-left discrimination is related to the right hemisphere. *Laterality.* 2008;**13**(5):427-38.
- Ofte SH, Hugdahl K. Right-left discrimination in male and female, young and old subjects. *J Clin Exp Neuropsychol.* 2002;**24**(1):82-92.
- Hirnstein M, Ocklenburg S, Schneider D, Hausmann M. Sex differences in left-right confusion depend on hemispheric asymmetry. *Cortex.* 2009;**45**(7):891-9.
- Corballis MC. Left brain, right brain: facts and fantasies. *PLoS Biol.* 2014;**12**(1):e1001767. Epub Jan 21.
- Ocklenburg S, Hirnstein M, Ohmann HA, Hausmann M. Mental rotation does not account for sex differences in left-right confusion. *Brain Cogn.* 2011;**76**(1):166-71.
- Mitchell P, Dale T. Side errors in neurosurgery and human factors training. *Acta Neurochir (Wien).* 2015;**157**(7):1155-6.
- NHS Improvement. Patient safety incident reporting and responding to patient safety alerts. NHS National Patient Safety Agency; 2017. Available from: <https://improvement.nhs.uk/news-alerts/patient-safety-incident-reporting-and-responding-patient-safety-alerts/> Last accessed October 2017.
- The Joint Commission. Improving patient and worker safety: opportunities for synergy, collaboration and innovation. Available from: <https://www.jointcommission.org/assets/1/18/TJC-ImprovingPatientAndWorkerSafety-Monograph.pdf> Oakwood Terrace, Illinois: Joint Commission; 2012. Last accessed October 2017.
- NHS Improvement. Never Events Data. London: NHS Improvement; 2017. Available from: <https://improvement.nhs.uk/resources/never-events-data/>. Last accessed October 2017.
- Miller KE, Mims M, Paull DE, Williams L, Neily J, Mills PD, *et al.* Wrong-side thoracentesis: lessons learned from root cause analysis. *JAMA Surg.* 2014;**149**(8):774-9.
- Gormley GJ, Dempster M, Best R. Right-left discrimination among medical students: questionnaire and psychometric study. *BMJ.* 2008;**337**:a2826.
- Reason J. Human error: models and management. *BMJ.* 2000;**320**(7237):768-70.
- Lekka C, Health and Safety Laboratory. High reliability organisations: a review of the literature. London: Health and Safety Executive; 2011. Available from: <http://www.hse.gov.uk/research/rrpdf/rr899.pdf>. Last accessed October 2017.
- The Royal College of Anaesthetists. Anaesthetists as educators (AaE) programme: AaE: Anaesthetists' Non-Technical Skills (ANTS). London: The Royal College of Anaesthetists; 2017. Available from: <http://www.rcoa.ac.uk/anaesthetists-educators-aae/aae-anaesthetists-non-technical-skills-ants>. Last accessed October 2017.
- Flin RH, O'Connor P, Crichton M. Safety at the sharp end: a guide to non-technical skills. Aldershot: Ashgate Publishing Lt; 2008.
- Fletcher G, Flin R, McGeorge P, Glavin R, Maran N, Patey R. Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system. *Br J Anaesth.* 2003;**90**(5):580-8.
- Helmreich RL, Merritt AC, Wilhelm, JA. The evolution of crew resource management training in commercial aviation. *Int J Aviat Psychol.* 1999;**9**(1):19-32.
- University of Aberdeen, The Royal College of Surgeons of Edinburgh, NHS Education for Scotland. The non-technical skills for Surgeons (NOTSS) System Handbook v1.2: structuring observation, rating and feedback of surgeons' behaviour in the operating theatre. Aberdeen: University of Aberdeen; 2012. Available from: <https://www.rcsed.ac.uk/media/415471/notss-handbook-2012.pdf>. Last accessed October 2017.
- Industrial Psychology Research Centre, University of Aberdeen. SPLINTS - scrub practitioners' list of intra-operative non-technical skills. Aberdeen: University of Aberdeen; 2014. Available from: <https://www.abdn.ac.uk/iprc/splints/>. Last accessed October 2017.
- Institute for Healthcare Improvement, Open School Module. PS103: human factors and safety. Cambridge, Massachusetts: Institute for Healthcare Improvement; 2015.
- Albert WW. Medical Error: the second victim. The doctor who makes the mistake needs help too. *BMJ.* 2000;**320**(7237):726-7.
- Pandit JJ, Matthews J and Pandit M. “Mock before you block”: an in-built action-check to prevent wrong-side anaesthetic nerve blocks. *Anaesthesia.* 2017;**72**(2):150-5.



32. Atkinson RC, Shiffrin RM. Human memory: a proposed system and its control processes. *Psychol Learn Motiv.* 1968;**2**:89-195.
33. Hollnagel E. The ETTO principle - efficiency-thoroughness trade-off. Esbjerg, Denmark: Erik Hollnagel; 2016. Available at <http://erikhollnagel.com/ideas/etto-principle/>. Last accessed October 2017.
34. McKinley J, Dempster M, Gormley GJ. 'Sorry, I meant the patient's left side': impact of distraction on left-right discrimination. *Med Educ.* 2015;**49**(4):427-35.
35. US Federal Aviation Regulations. Title 14: Aeronautics and Space. Part 121—Operating requirements: domestic, flag, and supplemental operations. Part 121.542 Flight crewmember duties. Washington DC: US Government Publishing Office; 2016. Available from: <https://www.ecfr.gov/cgi-bin/text-idx?SID=7170da34990bb8540d02dba9db545c5b&mc=true&node=pt14.3.121&rgn=div5>. Last accessed October 2017.
36. Anthony K, Wiencek C, Bauer C, Daly B, Anthony MK. No interruptions please: impact of a no interruption zone on medication safety in intensive care units. *Crit Care Nurse.* 2010;**30**(3):21-29.
37. World Health Organisation. Patient Safety: a World Alliance for Better Healthcare. Surgical safety checklist. Revised version. Geneva: World Health Organization; 2009. Available from: http://apps.who.int/iris/bitstream/10665/44186/2/9789241598590_eng_Checklist.pdf. Last accessed October 2017.
38. NHS England. Safe Anaesthesia Liaison Group. Nottingham University Hospitals. Clinical Quality Standards and Safety: Recommended Standards of Clinical Practice: Wrong Site Block. London: The Royal College of Anaesthetists; 2017. Available from: <http://www.rcoa.ac.uk/standards-of-clinical-practice/wrong-site-block>. Last accessed October 2017.
39. Havelock T, Teoh R, Laws D, Gleeson F, on behalf of the BTS Pleural Disease, Guideline Group. Pleural procedures and thoracic ultrasound: British Thoracic Society pleural disease guideline 2010. *Thorax.* 2010;**65**(Suppl 2):i61-i76.
40. The Royal College of Ophthalmologists. Standards: Publications & Research: Patient Safety Information: Bradford Macula Service Checklist: for Intra-vitreous injections ONLY (Adapted from the WHO Surgical Safety Checklist). Bradford: Royal College of Ophthalmologists; 2015. Available from: <https://www.rcophth.ac.uk/wp-content/uploads/2015/08/BradfordTeaching-Hospitals-NHS-Trust-Macula-Service-Theatre-Checklist-October-2014.pdf>. Last accessed October 2017.
41. Mitchell B, Cristancho S, Nyhof BB, Lingard LA. Mobilising or standing still? A narrative review of surgical safety checklist knowledge as developed in 25 highly cited papers from 2009 to 2016. *BMJ Qual Saf.* 2017;**26**(10):837-44.
42. Minn MJ, Zandieh AR, Filice RW. Improving Radiology Report Quality by Rapidly Notifying Radiologist of Report Errors. *J Digital Imaging.* 2015;**28**(4):492-8.
43. Dyer O. Doctors suspended for removing wrong kidney. *BMJ.* 2004(7434);**328**:246.
44. Alleyne R. Surgeons 'ignored student's warning over fatal error'. The Telegraph. 2002 Jun 13. Available from: <http://www.telegraph.co.uk/news/uknews/1397118/Surgeons-ignored-students-warning-over-fatal-error.html>. Last accessed October 2017.
45. Cosby KS, Croskerry P. Profiles in patient safety: authority gradients in medical error. *Acad Emerg Med.* 2004;**11**(12):1341-5.



UMJ is an open access publication of the Ulster Medical Society (<http://www.ums.ac.uk>).

The Ulster Medical Society grants to all users on the basis of a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International Licence the right to alter or build upon the work non-commercially, as long as the author is credited and the new creation is licensed under identical terms.