What do ICU doctors do? A multisite time and motion study of the clinical work patterns of registrars

Ling Li, Isla Hains, Toni Hordern, David Milliss, Ray Raper and Johanna Westbrook

ABSTRACT

Objective: To quantify the time that intensive care unit registrars spend on different work tasks with other health professionals and patients and using information resources, and to compare them with those of clinicians in general wards and the emergency department (ED).

Design, setting and participants: A prospective, observational time-and-motion study of two ICUs with a total of 71 beds at two major teaching hospitals in Sydney. Twenty-six registrars were observed between 08:00 and 18:00 on weekdays for a total of 160.52 hours.

Main outcome measures: Proportions of time spent on different tasks, using specific information resources, working with other health professionals and patients, and rates of multitasking and interruptions.

Results: A total of 12 043 distinct tasks were observed. Registrars spent 69.2% of time working at patients' bedsides, 49.6% in professional communication and 39.0% accessing information resources. Half of their time (53.8%) was spent with other ICU doctors and 29.2% with nurses. Compared with doctors and nurses on general wards, and doctors in the ED, ICU registrars were more likely to multitask (40.1 times/hour [24.4% of their time]). ICU registrars had a higher interruption rate than ward clinicians, (4.2 times/hour), but a lower rate than ED doctors.

Conclusions: Face-to-face communication and information seeking consume a vast proportion of ICU registrars' time. Multitasking and handling frequent interruptions characterise their work, and such behaviours may create an increased risk of task errors. Electronic clinical information systems may be particularly beneficial in this information-rich environment.

Crit Care Resusc 2015; 17: 159–166

The intensive care unit is a complex and dynamic environment where clinicians have the responsibility of caring for some of the most acutely ill patients in hospital. It is an information-rich environment, and ICU clinicians can be faced with over 1300 items of clinical information per day to aid them in caring for their patients.[1] Decision making is complex and involves collaboration between ICU clinicians, outside medical teams, as well as synthesising multiple information elements including flow charts, patient notes, medication charts, vital signs, test results and images.[2-4] ICU clinicians are generally thought to be time-poor, and the process of collating and organising this information is potentially made more complex through frequent interruptions and multitasking requirements.[5,6] Little evidence exists, however, to show how ICU clinicians spend their time managing information and caring for their patients. Understanding their task time distribution provides a useful basis from which to identify interventions to support more efficient work, for example to prevent unnecessary interruptions, as well as setting a baseline against which any such interventions can be assessed.

For our study, we chose to focus on the work of ICU registrars, given their central role in the provision of direct care to patients and in decision making in ICUs. Our observational work (unpublished) indicates that the role of a registrar is generally consistent across ICUs, but specialists each work differently, and residents are not always as involved in decision making. Our primary aim was to quantitatively measure the work patterns of ICU registrars, including how their time is spent, what information resources they use to assist their work, with whom they work and how often they multitask and are interrupted. We also compared ICU work patterns with those of other colleagues (ie, ward doctors, emergency department [ED] doctors and ward nurses).

Methods

Study design, setting and sample

We conducted a prospective, observational time and motion study in the ICUs of two tertiary Sydney teaching hospitals. Hospital A had 13 ICU beds and hospital B had 58. Paper notes were used in both hospitals during the study period, but test ordering, results and imaging were all performed electronically.

All ICU registrars were invited to participate in the study via information sessions followed by direct approaches, and all agreed. Among 26 registrars in the study (six from hospital A and 20 from hospital B), seven were senior

Table 1. Intensive care registrar task classification

Task category	Definition	Included activies
Direct care	All tasks directly related to patient care	Direct communication with patient and/or family (including "in transit"; eg, when taking a patient to radiology) Examining or reviewing a patient Medical emergency team calls Monitoring machines etc Performing medical procedures
Indirect care	All tasks indirectly related to patient care	Washing hands Putting on or removing gowns Getting paper forms or other paper documents such as flow sheets, medication charts, medical record etc Preparing for a procedure Cleaning up after a procedure Preparing or collecting medications Gathering and returning equipment Writing on or labelling test tube blood vials Waiting and thinking time Waiting for computer programs (eg, Powerchart) to load (can be very slow)
Documentation	Any recording of patient information on paper or computer	Using flow sheet, intensive care unit note, medical chart, paper results, computer results, orders for patients, images, paper reminders and lists and other resources
Reading	Any reading of patient information on paper or computer	Using flow sheet, intensive care note, medical chart, paper results, computer results, orders for patients, images, paper reminders and lists and other resources
Ordering	Placing a formal electronic order	Ordering a pathology or microbiology test Ordering imaging Ordering consults (eg, with allied health staff)
Professional communication	Any work-related discussion with another staff member	Discussion about patients on ward rounds Discussion about patients with any other health care professional Staff member receiving education from other staff member Handover meetings Radiology meetings Paging someone and returning a page
In transit	Work-related movement between patients and between tasks	When registrar moves between patients When registrar travels elsewhere in the ICU When registrar travels outside the ICU (NB: eg, when the registrar is taking a patient to radiology, "in transit" would be multitasking with "direct care")
Social activities	Any social or personal activity or discussion, as well as meal and tea breaks	Personal phone calls Social discussion between clinicians Tea and personal breaks Bathroom breaks Reading books and magazines
Other	Administrative: administrative activity not related to direct or indirect care (includes activities related to the running of the unit, but not related to direct or indirect patient care)	Duty rosters Employment issues Bed allocations Coordination of staff activities Staff meetings (not clinical meetings) Unit-related tasks
	Continuing education and meetings: teaching or education of another staff member and general education	Teaching on ward rounds Grand rounds Staff meetings concerning the department including weekly education sessions Self-directed learning from internet or paper materials, not related to any one patient

registrars and 19 were junior registrars. Observations occurred between 08:00 and 18:00 on weekdays and each session lasted about 2 hours. In total, we observed 160.52 hours in 80 sessions; 26 observation sessions were conducted at hospital A from September to November 2012 and 54 sessions at hospital B from March to April 2013.

Data collection and procedure

Observation sessions were randomly and proportionately allocated between junior and senior registrars using their rosters. We ensured that all hours of the workday and weekdays were evenly covered. After giving signed consent to participate, registrars were assigned a study identification number.

The work observation method by activity timing (WOMBAT) method was applied.[7-10] This is a technique for undertaking direct observational studies of health professionals. Using customisable software on a portable touchscreen tablet, observers capture multidimensional aspects of clinicians' work, such as what task is being undertaken, with whom, what they are using and where the task is being completed. The WOMBAT tool automatically captures all time data related to tasks and also measures interruptions and multitasking (ie, tasks conducted in parallel). An ICU task classification was devised (Table 1) and incorporated into the WOMBAT tool after extensive observation and pilot testing for our study (Figure 1). The final classification had nine broad, mutually exclusive work tasks. Ethics approval was obtained from the Human Research Ethics Committee of each hospital.

Observer training

One observer conducted all observations in Hospital A and a second observer assisted in the observations in Hospital B. The intra-rater reliability of the observations for the single observer at Hospital A was checked over time by examining the consistency of summary statistics (eg, the proportion of time spent on different tasks and the numbers of interruptions and instances of multitasking) during the data collection period. The first observer trained the second observer. Several rounds of inter-rater reliability testing were conducted until close agreement between the two observers was reached, based on κ statistics calculated using a previously established method for time and motion studies.[11] The final average score for task category, location, interruption, number of multitasking fragments, number of interruptions and interrupting tasks was $\kappa = 0.94$, indicating almost perfect observer agreement in task classification.

Statistical analysis

To describe the work pattern of registrars, we calculated the task time for each task (defined in Table 2), the proportion of total observation time on different tasks and the proportion of multitasking time, as well as the rates of multitasking and interruptions. Ninety-five per cent confidence intervals for the proportion of total time and the proportion of time on multitasking were obtained using the large sample normal approximation. The rates of multitasking and interruptions, including their 95% CIs, were calculated using Poisson regression. As registrars may adopt their own strategies when dealing with competing tasks, the correlation of tasks conducted by the same registrars was taken into account using the multilevel modelling approach for the calculation of multitasking rates. Other descriptive statistics, including number of tasks, average length of tasks and frequency of tasks over observation time, are also presented. The total observation time was used as a denominator to calculate the proportion of time spent accessing different information resources and with whom registrars worked. No differences in the work pattern or rates of multitasking and interruptions were observed between junior and senior registrars, so data for the two groups were combined for

Figure 1. Screenshot of Work Observation Method by Activity Timing (WOMBAT) data collection tool

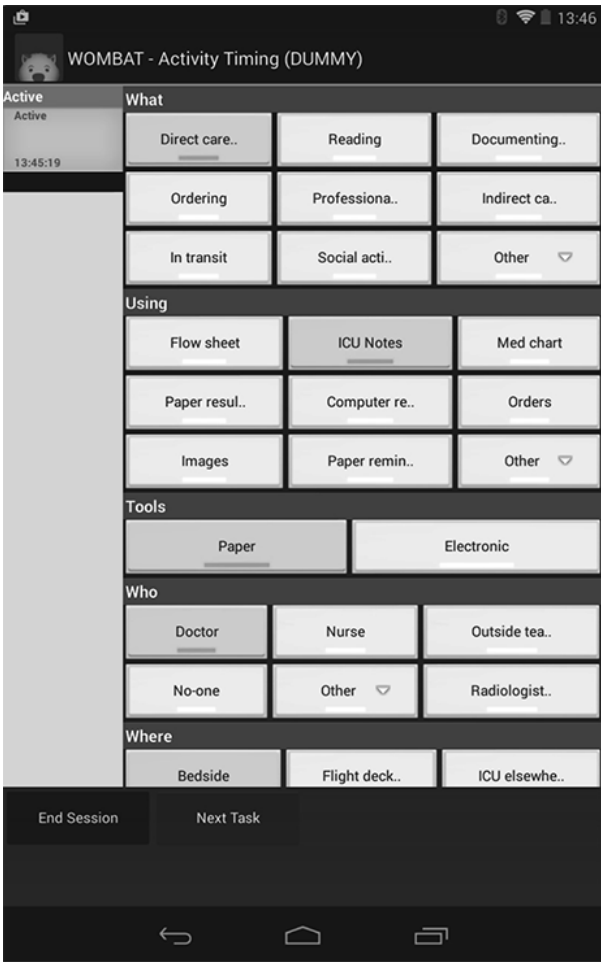

Table 2. Definitions of observation time and task time*

Total observation time:	total time when intensive care registrars are followed by observers (160.5 observation hours).
Task time:	calculated by adding time that registrars spent on a task over observation sessions. Total task time is the sum of task time on different tasks (199.7 task hours [Table 3]).

* Discrepancy between observation hours and task hours is due to multitasking (ie, registrars conducting tasks concurrently).

Table 3. Distributions of task time, multitasking time and interruption rate

Task category	No. of tasks	Task time (hours)	Av. task time (seconds)	Frequency of tasks	% Total observation time* (95% CI)	% Multitasking time spent on specific task (95% CI)	Interruption rate per hour (95% CI)
Direct care	806	26.2	117	5.0	16.4% (14.5%–18.2%)	42.1% (33.9%–50.2%)	2.2 (1.7–2.8)
Documenting	1084	18.5	61	6.8	11.5% (9.8%–13.3%)	56.7% (42.8%–70.6%)	8.6 (7.4–10)
In transit	1240	7.3	21	7.7	4.6% (4.2%–5.0%)	21.4% (16.9%–25.9%)	3.0 (2.0–4.6)
Indirect care	1942	18.1	34	12.1	11.3% (10.6%–11.9%)	30.7% (27.6%–33.9%)	4.1 (3.3–5.1)
Ordering	11	0.2	72	0.1	0.1% (0.1%–0.2%)	22.7% (0–47.7%)	9.1 (2.3–36.3)
Other	137	5.7	149	0.9	3.5% (1.7%–5.4%)	10% (3.8%–16.2%)	5.8 (4.2–8.2)
Professional communication	4335	79.5	66	27.0	49.6% (46.5%–52.7%)	39.2% (36.2%–42.3%)	3.1 (2.7–3.5)
Reading	1837	23.9	47	11.4	14.9% (13.2%–16.6%)	61.8% (50.9%–72.6%)	8.3 (7.2–9.5)
Social activity	651	20.1	111	4.1	12.5% (10.5%–14.5%)	8.4% (6%–10.8%)	1.7 (1.2–2.4)
Overall	*12 043*	*199.7*	*60*	*75.0*	–	–	*4.2 (3.9–4.5)*

* Percentages do not add to 100 as some tasks were undertaken at the same time (ie, when registrars were multitasking).

the analysis. Data were analysed using SAS, version 9.3 (SAS Institute Inc).

Results

Time spent on tasks

During the 160.5 hours of observation, a total of 12 043 distinct tasks were observed. The task-specific distribution of registrars' time is shown in Table 3. The most frequent task among all nine task categories was professional communication. On average, 27 professional communication tasks occurred per hour, which is more than double all other task categories. Professional communication comprised almost half of registrars' total time (49.6%), and appeared to be the dominant task through the day, as shown in Figure 2. Direct care accounted for the second highest proportion of time (16.4%), followed by reading (14.9%), social activities (12.5%), documenting (11.5%), indirect care (11.3%), other tasks (3.5%) and ordering (0.1%). Only 11 ordering tasks were observed, as most ordering was performed during the night shift or by residents.

Multitasking and interruptions

There was a total of 199.7 task hours spent on different tasks during the 160.5 hours of observation. The discrepancy between observation hours and task hours is due to multitasking, when registrars conducted two or more tasks concurrently. Registrars frequently conducted tasks concurrently (40.1 times/hour, 95% CI, 36.4–44.1 times/hour). The overall proportion of observed time on multitasking was 24.4% and this proportion varied depending on which task registrars were conducting. Time spent on multitasking was highest when a registrar was reading (61.8% of reading tasks were conducted with other tasks), followed by documenting (56.7%), direct care (42.1%) and professional communication (39.2%), as shown in Table 3.

A total of 678 tasks (5.7%) were interrupted during the study period, with some tasks being interrupted more than once. Registrars experienced 820 interruptions while performing these 678 tasks, representing an overall rate of 4.2 interruptions/task-hour (95% CI, 3.9–4.5 interruptions/task-hour). Although ordering tasks had the highest rate of interruptions (9.1 times per hour), only 11 ordering tasks were observed. As with multitasking, documenting and reading were more likely to be interrupted by other tasks, with interruption rates of 8.6 and 8.3 per hour, respectively (Table 3).

Figure 2. Time allocated to different tasks by intensive care registrars from 8:00 to 18:00

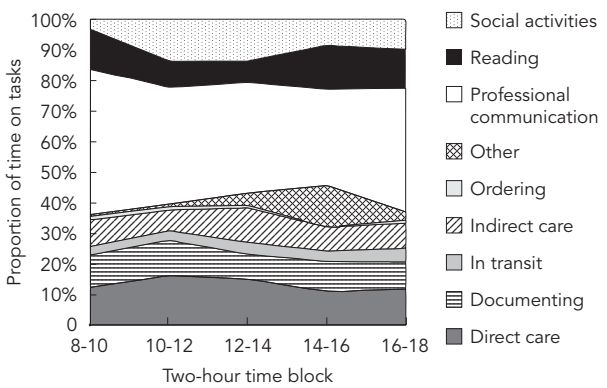

Table 4. Time spent by intensive care registars on using information resources and working with people

	No. of tasks	Mean task time (secs)	Task frequency	Percentage of total observation time (95% CI)
Information resource				
Flow sheet	300	29.6	1.9	1.5% (1.4%–1.7%)
ICU notes	946	60.6	5.9	9.9% (8.9%–10.9%)
Medication chart	422	33.1	2.6	2.4% (2.1%–2.7%)
Paper results	125	30.0	0.8	0.7% (0.5%–0.8%)
Computer results	295	57.0	1.8	2.9% (2.4%–3.5%)
Orders	41	55.5	0.3	0.4% (0.3%–0.5%)
Radiogical images	191	174.2	1.2	5.8% (4.4%–7.1%)
Paper reminders/lists	495	37.1	3.1	3.2% (2.8%–3.6%)
Other*	920	82.8	5.7	13.2% (10.3%–16.1%)
People registrars worked with				
ICU doctors	3696	84.1	23.0	53.8% (49.8%–57.9%)
ICU nurses	2450	68.9	15.3	29.2% (26.5%–32.0%)
Outside team	599	98.5	3.7	10.2% (8.7%–11.7%)
Radiologist	23	408.0	0.1	1.6% (0.7%–2.6%)
Allied health	66	148.3	0.4	1.7% (1.1%–2.3%)
Other	401	76.4	2.5	5.3% (4.5%–6.1%)
Patients	7439	53.8	46.3	69.2% (66.6%–71.9%)
No one	5866	47.2	36.5	47.9% (45.0%–50.9%)

ICU = intensive care unit. * Included handover summary on projector, phone, pager, electroglottography, discharge summary, film, paper order form, and all other information resources and documents.

Information resources used by registrars

ICU registrars used information resources to assist their work 39.0% of the total task time. The resources used are listed in Table 4. The most-used information resource were ICU notes (9.9% of the total task-hour), followed by radiological images (5.8%), paper reminders and lists (3.2%) and computer results (2.9%).

People with whom registrars worked

Registrars spent 76.4% of their time working with other health professionals. More than half of registrars' tasks (51.3%, $n = 6177$) were conducted with at least one other health professional. As shown in Table 4, 69.2% of the registrars' task time was spent with patients, followed by other ICU doctors (53.8%), ICU nurses (29.2%) and medical teams from outside the ICU (10.2%).

Comparisons with ward doctors, ED doctors and ward nurses

We compared our results with previously published studies of the work patterns of ward doctors,[10,12] ED doctors[12,13] and ward nurses[10,12] (Table 5). ICU registrars spent a similar amount of time on direct care as ward doctors, but substantially greater time on professional communication than their colleagues outside the ICU. ICU registrars allocated more time to patients than their colleagues. ICU registrars spent less time (54%) with other doctors compared with ward doctors, who spent 71% of their time with other doctors. ICU registrars spent considerably more time with nurses (29.2%) compared with ward doctors, who spent only 8% of their time with nurses. ICU registrars were more likely to multitask and be interrupted, having the highest multitasking rate (40.1 times/hour) and the second highest interruption rate (4.2 times/task hour) among all health professionals (Table 5).

Discussion

To our knowledge, ours is the first large comprehensive time-and-motion study to quantify work patterns of ICU registrars. We provide a picture of ICU registrars' task-time distribution, information use and interdisciplinary collaboration. Our results reflect how registrars manage their time in such a dynamic, demanding and complex critical care environment. Registrars had to deal with frequent interruptions and had to multitask to meet work demands, all of which have the potential to affect the quality of care delivery.

ICU registrars spent more than half their time working at the bedsides of patients, which was about four times the

Table 5. Comparisons of work patterns among intensive care registrars, ward doctors, ED doctors and ward nurses

Setting	Intensive care registrars	Ward doctors*	ED doctors†	Ward nurses*
Clinicians, *n*	26	12	40	22
Wards, *n*	2	2	1	2
Hospitals, *n*	2	1	1	1
Time observed, hours	160.5	98.7	210.8	103.8
Percentage of observed time spent on tasks (95% CI)				
Direct care	16.4% (14.5%–18.2%)	14.5% (11.4%–17.7%)	28.6%(26.4%–30.8%)	20.1% (18.0%–22.3%)
Professional communication*	49.6% (46.5%–52.7%)	33.5% (28.2%–38.8%)	24.2%(22.9%–25.4%)	23.7% (20.4%–27.1%)
Percentage of observed time spent with other health professionals (95% CI)				
Doctors	53.8% (49.8%–57.9%)	70.7% (62.6%–78.7%)	–	3.4% (3.0%–3.8%)
Nurses	29.2% (26.5%–32%)	7.7% (5.8%–9.6%)	–	49.5% (44.5%–54.5%)
Patients	69.2% (66.6%–71.9%)	17.7% (15.0%–20.5%)	–	32.9% (30.7%–35.1%)
Interruption rate (95% CI)‡	4.2% (3.9%–4.5%)	2.2% (2.1%–2.4%)	6.0% (5.7%–6.4%)	1.8% (1.7%–2.0%)
Multitasking rate (95% CI)‡	40.1% (36.4%–44.1%)	17.3% (16.9%–17.8%)	9.2% (8.8%–9.6%)	14.1% (13.8%–14.5%)

ED = emergency department. * Proportions of total observation time spent on different tasks and the proportions of time with other health professionals for ward doctors and nurses are from a study by Westbrook and colleagues for control wards before the introduction of an electronic medication management system.[10] † Proportions of total observation time spent on different tasks and the proportions of time with other health professionals for ED doctors are from a study by Westbrook and colleagues.[14] ‡ Comparison of interruption and multitasking rates are from a study by Walter and colleagues.[13]

proportion of the time ward doctors spent with patients.[10] Professional communication was a dominant task for registrars throughout the day. Registrars used nearly half their time on professional communication, which was far more than ward doctors, ED doctors or ward nurses in previous studies.[10,13] This result is consistent with a Canadian observational study of 18 ICU doctors over 58 hours, which found that about 75% of their time was spent on professional communication.[7] More than half the work of ICU registrars was conducted with at least one other health professional. Previous studies show that interdisciplinary collaboration among nurses and doctors is recognised as crucial for improving quality and safety in acute care,[14] including in the ICU.[15] Registrars spent more than half their time with other ICU doctors. Compared with ward doctors, ICU registrars spent more time collaborating with nurses (29.2% for ICU registrars versus 7.7% for ward doctors), which is representative of the culture in the ICU where one nurse is usually assigned to look after a single patient, compared with nurses on wards who are responsible for several patients. These results reflect the necessity for high levels of interdisciplinary collaboration in dealing with acutely ill patients whose conditions can rapidly change.

ICU registrars were more likely to multitask than ward doctors, ED doctors or ward nurses.[12] The frequency of interruptions to tasks of ICU registrars was also high, compared with ward doctors, but was lower than that experienced by ED doctors. The tasks of reading and documenting were most likely to be interrupted, and also were the most likely to be conducted simultaneously with other tasks. Interruptions to work have been associated with increased task errors in experimental studies[16] as well as in field studies in hospitals. For example, Australian nurses at two hospitals were found to make significantly more medication administration errors and more severe errors as interruptions increased.[17] However, it is also important to recognise that not all interruptions are negative and some may in fact be life-saving in a clinical setting.[18] Training and specific interventions may reduce potential negative impacts of interruptions.[19] Multitasking has also been shown in other environments to increase the risk of error.[20] The most well known example is the increased risk of accidents associated with driving and using a mobile phone. Legislation banning phone use while driving has been estimated to have reduced car fatalities by 10%.[21] Even commonplace multitasking such as driving while listening to someone talk has been shown to reduce driver performance.[22] We still know very little about the effects of multitasking on clinical work and, given the high rates observed, we have identified it as an area warranting further investigation.[23]

Registrars used various information resources to assist their work (in 39% of the total task time). ICU notes were the most frequently accessed resource, and registrars also

accessed a range electronic and paper documents. Apart from test ordering, results and imaging, paper notes were used in both study hospitals during the study period. Finding information needed from different resources can be time consuming, particularly when it is necessary to travel between different work areas to access information. Electronic health record systems may greatly assist ICU clinicians in managing and organising information to support decision making, particularly when there is a single unified interface for all existing information systems in a hospital, including those for pharmacy, clinical laboratory, radiology, patient monitoring, clinical documentation and other specialised systems.[24] The introduction of such electronic clinical information systems is purported to have a significant impact on the work of ICU clinicians, on efficiency, error reduction and the quality of care provision.[25-28] However, there is still a limited understanding of the ways in which clinical work may be affected by the introduction of these systems; if they will indeed result in more efficient work[29] and their effectiveness in supporting decision making.

Our study provides a valuable baseline understanding of the patterns of work experienced by ICU registrars. These findings provide the basis for investigation of changes in the work and communication patterns of registrars over time, and after the introduction of interventions such as new electronic information systems that might also alter strategies to deal with competing tasks. Future studies should also look at determining the impact of interruptions and multitasking on the quality of care in this critical care environment.

Competing interests

None declared.

Author details

Ling Li, Senior Research Fellow[1]
Isla Hains, Research Fellow[1]
Toni Hordern, Research Assistant[2]
David Milliss, Intensivist,[3] and Director[4]
Ray Raper, Intensivist and Director[5]
Johanna Westbrook, Director[1]

1 Centre for Health Systems and Safety Research, Australian Institute of Health Innovation, Faculty of Medicine and Health Sciences, Macquarie University, Sydney, NSW, Australia.

2 National Drug and Alcohol Research Centre, University of New South Wales, Sydney, NSW, Australia.

3 Intensive Care Services, Concord Hospital, Sydney, NSW, Australia.

4 Intensive Care Medicine, University of Sydney, Sydney, NSW, Australia.

5 Intensive Care Unit, Royal North Shore Hospital, Sydney, NSW, Australia.

ling.li@mq.edu.au

References

1 Manor-Shulman O, Beyene J, Frndova H, et al. Quantifying the volume of documented clinical information in critical illness. *J Crit Care* 2008; 23: 245-50.

2 Alberdi E, Gilhooly K, Hunter J, et al. Computerisation and decision making in neonatal intensive care: a cognitive engineering investigation. *J Clin Monit Comput* 2000; 16: 85-94.

3 Brown PJ, Borowitz SM, Novicoff W. Information exchange in the NICU: what sources of patient data do physicians prefer to use? *Int J Med Inform* 2004; 73: 349-55.

4 Miller A, Weinger MB, Buerhaus P, et al. Care coordination in intensive care units: communicating across information spaces. *Hum Factors* 2010; 52: 147-61.

5 Malhotra S, Jordan D, Shortliffe E, et al. Workflow modeling in critical care: piecing together your own puzzle. *J Biomed Inform* 2007; 40: 81-92.

6 Patel VL, Zhang J, Yoskowitz NA, et al. Translational cognition for decision support in critical care environments: a review. *J Biomed Inform* 2008; 41: 413-31.

7 Ballermann M, Shaw N, Mayes D, et al. Validation of the work observation method by activity timing (WOMBAT) method of conducting time-motion observations in critical care settings: an observational study. *BMC Med Inform Decis Mak* 2011; 11: 32.

8 Westbrook JI, Ampt A. Design, application and testing of the work observation method by activity timing (WOMBAT) to measure clinicians' patterns of work and communication. *Int J Med Inform* 2009; 78 Suppl 1: S25-33.

9 Westbrook JI, Creswick NJ, Duffield C, et al. Changes in nurses' work associated with computerised information systems: opportunities for international comparative studies using the revised Work Observation Method By Activity Timing (WOMBAT). *Nurs Inform* 2012: 448.

10 Westbrook JI, Li L, Georgiou A, et al. Impact of an electronic medication management system on hospital doctors' and nurses' work: a controlled pre–post, time and motion study. *J Am Med Inform Assoc* 2013.

11 Li L. Assessing inter-observer reliability in time and motion studies. Australiasian Applied Statistical Conference, Port Lincoln, South Australia. AASC, 2014: 62. http://aasc.org.au/cms/wp-content/uploads/2014/11/AASC-2014-Conference-Booklet-V4.pdf (accessed Jul 2015).

12 Walter SR, Li L, Dunsmuir WTM, et al. Managing competing demands through task-switching and multitasking: a multi-setting observational study of 200 clinicians over 1000 hours. *BMJ Qual Saf* 2014; 23: 231-41.

13 Westbrook JI, Coiera E, Dunsmuir WTM, et al. The impact of interruptions on clinical task completion. *Qual Saf Health Care* 2010; 19: 284-9.

14 Martin JS, Ummenhofer W, Manser T, Spirig R. Interprofessional collaboration among nurses and physicians: making a difference in patient outcome. *Swiss Med Wkly* 2010; 140: w13062.

15 Baggs JG, Schmitt MH, Mushlin AI, et al. Association between nurse–physician collaboration and patient outcomes in three intensive care units. *Crit Care Med* 1999; 27: 1991-8.

16 Bailey BP, Konstan JA. On the need for attention-aware systems: measuring effects of interruption on task performance, error rate, and affective state. *Comput Human Behav* 2006; 22: 685-708.

17 Westbrook JI, Woods A, Rob MI, et al. Association of interruptions with an increased risk and severity of medication administration errors. *Arch Intern Med* 2010; 170: 683-90.

18 Zijlstra FRH, Roe RA, Leonora AB, et al. Temporal factors in mental work: effects of interrupted activities. *J Occup Organ Psychol* 1999; 72: 163-85.

19 Zish K, Trafton JG. Interruption practice reduces procedural errors at the post-completion step. *Proc Hum Factors Ergon Soc Annu Meet* 2014; 58: 265-9.

20 Sanbonmatsu DM, Strayer DL, Medeiros-Ward N, et al. Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking. *PLoS One* 2013; 8: e54402.

21 Rocco L. Are hand-held cell-phone and texting bans really effective in reducing fatalities? University of Illinois; 2013.

22 Just MA, Keller TA, Cynkar J. A decrease in brain activation associated with driving when listening to someone speak. *Brain Res* 2008; 1205: 70-80.

23 Westbrook JI. Interruptions and multi-tasking: moving the research agenda in new directions. *BMJ Qual Saf* 2014; 23: 877-9.

24 Drews FA. Human factors in critical care medical environments. *Rev Hum Factors Ergon* 2013; 8: 103-48.

25 Bosman RJ. Impact of computerized information systems on workload in operating room and intensive care unit. *Best Pract Res Clin Anaesthesiol* 2009; 23: 15-26.

26 Fraenkel DJ, Cowie M, Daley P. Quality benefits of an intensive care clinical information system. *Crit Care Med* 2003; 31: 120-5.

27 Hains IM, Creswick N, Westbrook JI. Does PACS facilitate work practice innovation in the intensive care unit? *Stud Health Technol Inform* 2011; 169: 397-401.

28 Morrison C, Fitzpatrick G, Blackwell A. Multi-disciplinary collaboration during ward rounds: embodied aspects of electronic medical record usage. *Int J Med Inform* 2011; 80: e96-111.

29 Mador RL, Shaw NT. The impact of a critical care information system (CCIS) on time spent charting and in direct patient care by staff in the ICU: a review of the literature. *Int J Med Inform* 2009; 78: 435-45. ❑