Resuscitation 82 (2011) 150–154

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

An eight year audit before and after the introduction of modified early warning score (MEWS) charts, of patients admitted to a tertiary referral intensive care unit after CPR☆

A. Moon, J.F. Cosgrove*, D. Lea, A. Fairs, D.M. Cressey

Department of Perioperative and Critical Care, Freeman Hospital, Newcastle Upon Tyne NE7 7DN, United Kingdom

ARTICLE INFO

Article history:
Received 29 June 2010
Received in revised form 2 September 2010
Accepted 27 September 2010

Keywords:
Cardiac arrest
Critical care outreach
Cardiopulmonary resuscitation
Outcome

ABSTRACT

Aims: To determine whether cardiac arrest calls, the proportion of adult patients admitted to intensive care after CPR and their associated mortalities were reduced, in a four year period after the introduction of a 24/7 Critical Care Outreach Service and MEWS (Modified Early Warning System) Charts.
Methods: A retrospective analysis of prospectively collected data during two four-year periods, (2002–05 and 2006–09) in a UK University Teaching Hospital Comparisons were via χ^2 test. A p value of ≤ 0.05 was regarded as being significant.
Results: In the second audit period, compared to the first one, the number of cardiac arrest calls relative to adult hospital admissions decreased significantly (0.2% vs. 0.4%; $p < 0.0001$), the proportion of patients admitted to intensive care having undergone in-hospital CPR fell significantly (2% vs. 3%; $p = 0.004$) as did the in-hospital mortality of these patients (42% vs. 52%; $p = 0.05$).
Conclusion: The four years following the introduction of a 24/7 Critical Care Outreach Service and MEWS Charts were associated with significant reductions in the incidence of cardiac arrest calls, the proportion of patients admitted to intensive care having undergone in-hospital CPR and their in-hospital mortality.

1. Introduction

Failure to identify acute physiological deteriorations in acutely ill patients and act upon them can result in increased severity of illness; worsening morbidity and mortality particularly when cardio-respiratory arrest occurs.[1–5] During the 1990s, audit in the UK noted increased mortality rates in ward-based intensive care admissions compared to those from operating theatres and Accident and Emergency Units.[6] Authors raised concerns about standards of practice in relation to detection of clinical deterioration and consequently developed the principle of "early recognition" via Early Warning Scores (EWS) to trigger skilled, experienced senior help for at-risk patients.[7]

Review of EWS in 2000 noted that *regular use of such charts ensured earlier and more appropriate intensive care referrals* and EWS evolved into MEWS (Modified Early Warning Score) with further potential for identifying at-risk patients.[8] MEWS recognises that patients' conditions frequently deteriorate over several hours and by regularly monitoring the basic clinical indicators of oxygen delivery (respiratory rate, heart rate, blood pressure, oxygen saturation) and tissue perfusion (capillary refill time, conscious level, oxygen saturation, urine output) ward-staff can gauge relative stability, triggering assistance when necessary (Figs. 1 and 2). Increased MEWS scores have been associated with increased mortality and NCEPOD (National Confidential Enquiry into Patient Outcome and Death) has referred to this association when stating the need for early recognition of critically ill patients.[9–11]

In the UK these issues precipitated guidance from the Audit Commission and Department of Health with the latter using the publication *Comprehensive Critical Care* to recommended their use in May 2000.[12,13] Additionally the facilitators of early recognition of at-risk patients were recommended as being the Critical Care Outreach Service or CCOS.[7,14–16] Where cardiac arrests occurred outcomes were deemed dependent on effective cardiopulmonary resuscitation (CPR) and appropriate critical care interventions, consequently *Comprehensive Critical Care* stated that CCOS effectiveness would be gauged by measures related to intensive care outcome; they included severity of illness on admission to intensive care, mortality (intensive care and in-hospital) and re-admission rates.[13,17] Other markers were the number of cardiac arrest calls in the hospital and the proportion of patients admitted to intensive care having undergone CPR.[12,13] To measure such outcomes, data collection would also be necessary.[12,13,16]

☆ A Spanish translated version of the abstract of this article appears as Appendix in the online version at doi:10.1016/j.resuscitation.2010.09.480.

* Corresponding author. Tel.: +44 191 2231059; fax: +44 191 2231180.
E-mail address: joe.cosgrove@nuth.nhs.uk (J.F. Cosgrove).

0300-9572/$ – see front matter © 2010 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.resuscitation.2010.09.480

NUTH NHS Trust Modified Early Warming System (MEWS)[1]

Score	3	2	1	0	1	2	3	Home Team Variants Name & Date
CNS		Confused /agitated		Alert	Respond to Voice	Respond to Pain	No response	
Respiratory rate	<8			8-20	21-30		>30	
Heart rate	<40		40-50	51-100	101-110	111-130	>130	
Systolic BP	<70	71-80	81-100	101-180	181-200	201-220	>220	
Temperature	<34	34.0-35.0		35.1-37.5	37.6-38.5	38.6-40.0	>40	
O2 Sats with appropriate oxygen therapy	< 90%	91-93%		94-100%				
Urine Output (Over 2 hrs or more)	<30ml/hr							

Fig. 1. MEWS (modified early warning score) chart.

The Freeman Hospital (FH) accordingly established a CCOS in 2001 consisting of six week-day sessions for consultant intensivists, supported by two senior intensive care nurses (1.5 whole time equivalents or WTEs). Initially the service directly supported a geographically separate high dependency unit (HDU) and the hospital's surgical wards. From August 2003 (when a new intensive care unit opened) the service expanded to cover other ward areas and with 6.5 WTEs in 2005 became 24/7, an important development in that survival rates from in-hospital cardiac arrests are known to be lower during nights and weekends.[18] The profile of the CCOS increased and in addition to clinical support to wards, education was provided with respect to early recognition of at-risk patients and the use of MEWS charts (Figs. 1 and 2).[19] At the same time service reconfiguration within the Newcastle upon Tyne Hospitals resulted in all acute medical admissions being referred to another hospital (the Royal Victoria Infirmary or RVI) where MEWS-charts had a similar developmental background. Additionally the Trust's Resuscitation Committee introduced "Do Not Attempt CPR" (DNACPR) forms in 2005 with the aim of reducing the incidence of futile CPR.

Further developments included the introduction of a locally installed intensive care database in 2001 designed to capture intensive care outcome measures, e.g. mortality rates and severity of illness on admission as judged by their APACHE (Acute Physiology and Chronic Health Evaluation) II score. This was replaced in 2006 by the Intensive Care National Audit and Research Council Case Mix Programme (ICNARC-CMP) which in addition to APACHE II had its own severity of illness scoring system shown to be a greater predictor of hospital mortality.[20] A series of local changes therefore occurred as a consequence of national trends in critical care services; they culminated in the introduction of

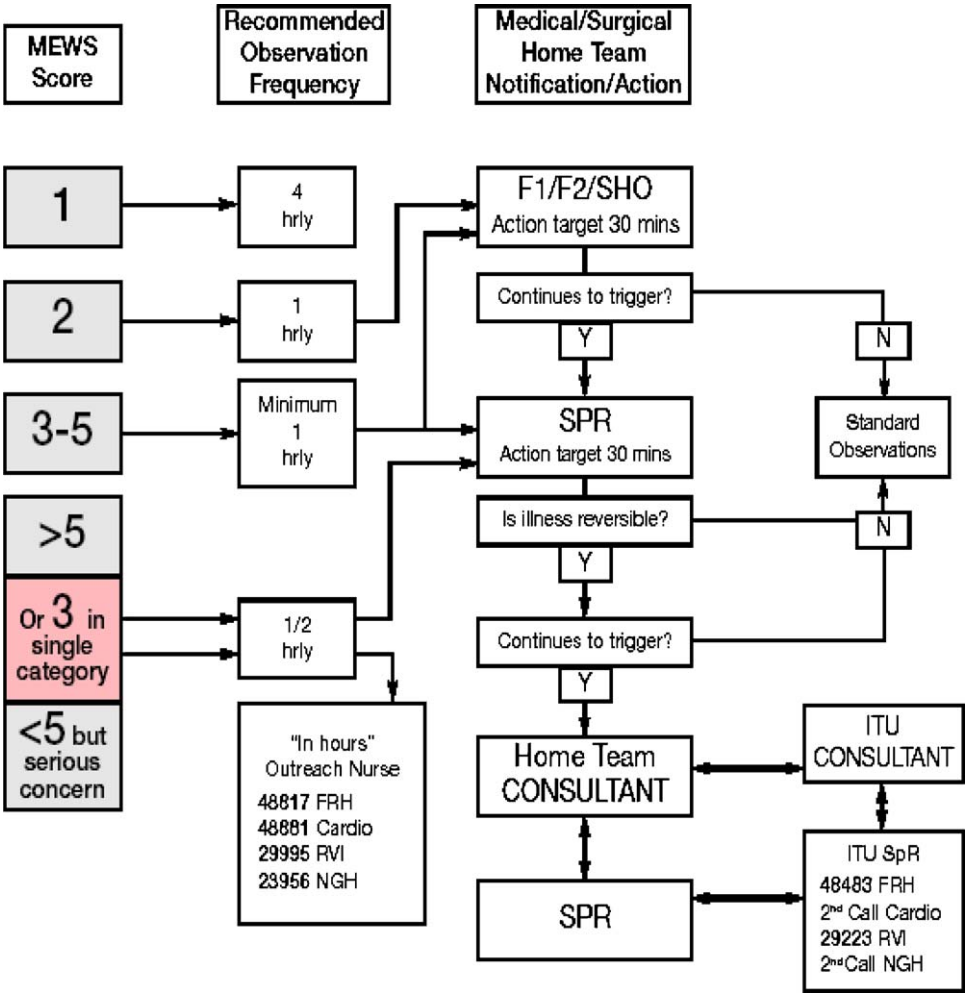

Fig. 2. Flow chart guiding the appropriate action recommended when a patient's observations trigger a particular MEWS score.
Newcastle Upon Tyne Hospitals NHS Foundation Trust

Table 1
Freeman adult admission data and adult cardiac arrest calls.

Measure	2002–2005	2006–2009	*p* value
Total admissions to hospital	213 117	235 516	n/a
Annual hospital admission rate	53 279	58 879	10.5% increase
Emergency Admissions to hospital (% of total admissions)	66 305 (31%)	66 457 (28%)	<0.001
Cardiac arrest calls as proportion of all adult admissions	767 (0.4%)	584 (0.2%)	<0.0001
Cardiac arrest calls as proportion of emergency admissions to hospital	767 (1.2%)	584 (0.9%)	<0.0001
Hospital deaths: total (annual rate)	3001 (750/year)	2789 (697/year)	7.1% decrease
Deaths per hospital admission	3001 (1.4%)	2789 (1.2%)	<0.0001
Deaths per emergency admission	3001 (4.5%)	2789 (4.2%)	<0.0001
Cardiac arrest calls per hospital death	767 (26%)	584 (21%)	<0.0001

MEWS charts, a 24/7 CCOS and re-location of acute medical admissions.

2. Methods

Best practice dictates that data collection and audit have a key role in monitoring the impact of such changes. We therefore performed a retrospective analysis of prospectively collected data in two four-year periods; 2002–05 and 2006–09. The second period being the four years, following the introduction of MEWS charts, 24/7 CCOS and re-location of acute medical admissions.

The primary aims were to assess whether (in the 2006–09 period) there had been a reduction in the proportion of cardiac arrest calls and an improvement in outcomes of adult patients admitted to intensive care after CPR. The following data was collected: annual adult admissions to hospital (total and emergency), intensive care admission rates, cardiac arrest calls to adult care areas, admission to intensive care following in-hospital CPR and mortality rates (intensive care and in-hospital) of these patients. The secondary aims were to assess severity of illness (via APACHE II) at intensive care admission, gender and age plus any possible impact from the relocation of acute medical services on these outcomes (via analysis of cardiac arrest calls and intensive care outcomes at the RVI).

A local intensive care database provided data on intensive care admissions for the period 2002–05 and data from the ICNARC-CMP provided data for 2006–09. Data for adult hospital admissions, mortality and cardiac arrest calls to adult care areas came from Information Services, Newcastle upon Tyne Hospitals NHS Foundation Trust. Admission rates were analysed by direct percentage comparisons, APACHE II scores and age compared via the Mann–Whitney *U*-test for non-parametric data. All other comparisons were via χ^2 test. A *p* value of $\leq$0.05 was regarded as being significant.

3. Results

Total adult admissions to FH (2002–05 vs. 2006–09) numbered 213 117 and 235 516 respectively. The overall annual admission rate increased by 10.5% with the proportion of emergency admissions reducing from 31% ($n = 66\,305$) to 28% ($n = 66\,457$; $p < 0.001$) (Table 1). The second audit period was associated with a significant reduction in the proportion of cardiac arrest calls to adult care areas, relative to both total admissions and emergency admissions (767 vs. 584; $p < 0.0001$). Hospital deaths reduced from 750/year in 2002–05 ($n = 3\,001$) to 697/year in 2006–09 ($n = 2789$), a 7.1% reduction. Deaths rates per adult admission (1.4% vs. 1.2%), per emergency admission (4.5% vs. 4.2%) and per cardiac arrest call were all significantly reduced ($p < 0.0001$).

With respect to secondary outcome measures (Table 2) the second audit period was associated with a 24.5% increase in annual admissions to intensive care (857/year vs. 1135/year), significant reductions in the proportion of patients admitted having undergone CPR (3% ($n = 101$) vs. 2% ($n = 101$); $p = 0.004$) and significant reductions in their in-hospital mortality (52% vs. 42%; $p = 0.05$).

At the RVI the annual admission rate increased by 14% in the period 2006–09 (Table 3). There was no increase in the proportion of emergency admissions (42% vs. 41%, $p = 0.8$), the proportion of cardiac arrest calls decreased significantly (723/213 117 admissions vs. 668/235 516 admissions, $p < 0.0001$) as did the proportion of adult deaths per admission in the hospital (3709 (1.4% of admissions) vs. 3622 (1.2% of admissions), $p < 0.0001$). With respect to intensive care outcomes at the RVI the annual admission rate increased by 54% in the second audit period and the proportion of patients admitted to intensive care having undergone CPR before admission reduced significantly (143 vs. 87, $p < 0.0001$). The difference in the median age of the patients was non-significant (68 years vs. 69 years, $p = 0.3$) and there was a non-significant increase in the severity of illness at admission as judged by APACHE II scores (18 vs. 21, $p = 0.13$). The intensive care mortality of patients admitted to intensive care having undergone CPR fell significantly (63% ($n = 90$) vs. 32% ($n = 28$), $p < 0.0001$) as did their in-hospital mortality (70% vs. 40%, $p < 0.0001$).

4. Discussion

After approximately 10-years the overall effectiveness of critical care outreach and equivalents remains uncertain. Evidence from Australia has linked the introduction of Medical Emergency Teams (METs) with reductions in cardiac arrest and mortality

Table 2
FRH intensive care outcome measures.

Measure	2002–2005	2006–2009	*p* value
ICCU admissions	3427	4540	n/a
Annual ICCU admission rate	857	1135	24.5% increase
CPR before admission	101 (3%)	101 (2%)	0.004
Male	69% ($n = 70$)	57% ($n = 58$)	0.012
Female	31% ($n = 31$)	43% ($n = 43$)	
Age: median (range)	68 (20–93)	69 (31–91)	0.9
APACHE II: median (range)	18 (15–45)	21 (0–47)	0.12
ICCU deaths of CPR patients	43% ($n = 43$)	36% ($n = 36$)	0.15
Ward deaths post-ICCU discharge	9	6	0.3
Total mortality of CPR cases	52% ($n = 52$)	42% ($n = 42$)	0.05

Table 3
RVI adult admission data and adult cardiac arrest calls.

Measure	2002–2005	2006–2009	*p* value
Total admissions to hospital	248 260	281 831	n/a
Annual hospital admission rate	62 065	70 458	14% increase
Emergency Admissions to hospital (% of total admissions)	103 240 (42%)	114 003 (41%)	0.8
Cardiac arrest calls as proportion of emergency admissions to hospital	723	669	<0.0001 7.5% decrease
Cardiac arrest calls as proportion of all adult admissions	723	669	<0.0001
Hospital deaths: total (annual rate)	3709 (952)	3622 (906)	2.3% decrease
Deaths per hospital admission	3709	3622	<0.0001
Deaths per emergency admission	3709	3622	<0.0001
Cardiac arrest calls per hospital death	723	669	0.12

rates and work in the UK has suggested a reduction in intensive care re-admission rates.[21,22] In the UK a randomised study on a single hospital site demonstrated significant reductions in hospital mortality when patients were cared for on wards where a critical care outreach service was functioning and in Australia a multi-faceted approach (clinical and educational) has also demonstrated improved outcomes in emergency admissions to intensive care.[23,24] However, larger multi-centre evidence has failed to demonstrate any reduction in cardiac arrests and unplanned intensive care admissions.[25] CCOS effectiveness therefore remains uncertain and debate continues with recent discussions focussing on both the benefits and cost effectiveness of outreach services.[26,27] Discussion of our results is therefore necessary to gauge their contribution to this debate.

The second audit period (2006–09) was associated with significant reductions in cardiac arrest calls at FH plus reduced numbers and mortality of patients admitted to intensive care having undergone CPR. The ages (68 vs. 69 years; $p = 0.9$) and severity of illness on admission to intensive care (APACHE II 18 vs. 21; $p = 0.12$) were not significantly different suggesting such patient characteristics had minimal influence on measured outcomes.[12,13] These changes (which occurred after the introduction of MEWS charts and a 24/7 CCOS in 2005) may reflect improved care.

At FH the adult mortality rate relative to "all adult admissions" and "all adult emergency admissions" reduced by 7.1% in the second audit period. The CCOS and its interactions with ward-based specialties may have contributed to this however changes in ward care and referral patterns from primary care cannot be discounted.[28] Nevertheless these improvements may be a positive reflection on the interaction of the CCOS with ward-based specialties, i.e. earlier recognition of at-risk patients has improved, reducing cardio-respiratory arrests in a ward setting and improving intensive care outcomes of patients undergoing CPR, despite there being an increased intensive care work-load and no reduction in APACHE II severity of illness on intensive care admission (Tables 1 and 2).

The loss of acute medical admissions was another potential factor influencing outcomes, i.e. service reconfiguration "may have just moved the problem" of acutely ill medical patients more at risk of physiological deterioration. Whilst emergency admissions at FH fell from 31% to 28% of all adult admissions (Table 1) there was minimal change in the proportion of adult emergencies admitted to the RVI (42% vs. 41%) despite a 14% increase in the adult admission rate (Table 3) during the second audit period. Additionally the proportion of cardiac arrest calls and incidence of CPR before intensive care admission fell significantly (Tables 3 and 4) suggesting corresponding improvements at the RVI, where similar developments had occurred with respect to the introduction of MEWS charts. Therefore the move of acute medical admissions did not appear to influence improved markers of care on either site although its effects are hard to fully assess.

Before concluding, limitations should be considered. This audit was a retrospective comparison of prospectively collected data and despite minimal variation in markers such as age and severity of illness, the two groups were not parallel streams of patients, undergoing a (single) study intervention in a clinical trial that researchers were blinded to. Additionally the retrospective nature of the study has the potential to miss changes in disease patterns and aforementioned admission patterns.[28] Furthermore the impact of a significant increase in female patients was not analysed and the timing of the cardiac arrest calls was not documented, noting studies that demonstrate worse outcomes at night and weekend.[18] Data collection with respect to "cardiac arrest calls" also requires consideration for although reducing "numbers of cardiac arrest calls" was a stated aim of CCOS-effectiveness the measure may be limited, i.e. within our own NHS Trust it merely reflects the number of cardiac arrest calls logged with the switchboard; there is no accurate record of false alarms, patients resuscitated on the ward and cared for there (or elsewhere, e.g. coronary care), calls for other medical emergencies or accidental calls for patients designated as "not for CPR".

In addition the (unknown) incidence of assigning DNACPR forms may also have improved this measured outcome, although their overall impact on care remains uncertain, i.e. dying patients were spared CPR, but what form of care subsequently occurred? This is currently difficult to answer as the impact and influence of services such as Palliative Care was not audited, although within our hospital's Renal Medicine Department decisions to limit levels of active treatments have seen an associated significant increase in palliative care referrals.[29] Further local audit of the incidence of "DNACPR", palliative care referral and the introduction of a National Cardiac Arrest Audit (NCCA) data may help to clarify such matters.[30]

Finally, an economic evaluation of the audit would have enhanced the discussion. Whilst clinicians rarely use this as an

Table 4
RVI intensive care outcome measures.

Measure	2002–2005	2006–2009	*p* value
ICCU admissions	2151	3308	n/a
Annual ICCU admission rate	538	827	54% increase
CPR before admission	143	87	<0.0001
Age: median (range)	68 (19–93)	69 (31–91)	0.3
APACHE II: median (range)	18 (13–49)	21 (10–45)	0.13
ICCU deaths of CPR patients	63% ($n = 90$)	32% (28)	<0.0001
Ward deaths post-ICCU discharge	10	7	0.7
Total mortality of CPR cases	70% ($n = 100$)	40% ($n = 35$)	<0.0001

outcome measure, the matter is increasingly at the forefront of health-care planning and has been raised specific to critical care outreach.[26,27] This is therefore a consideration for future audit, where changes in outcomes within patient groups over time could be plotted and evaluated in both clinical and health economic contexts as changes in practise are introduced.[26,31]

Thus in summary, our data showed significant improvements in overall hospital mortality rates, reductions in cardiac arrest calls, reductions in the proportion of patients having received in-hospital CPR prior to intensive care admission and improved hospital-survival of such patients. The introduction of MEWS charts and a 24/7 CCOS should be considered as a positive influence although other factors may have also had a significant impact on outcomes and it is therefore difficult to quantify specific effects. We can however conclude that there has been an improvement in outcome measures since the introduction of MEWS charts and a 24/7 CCOS and whilst definitive assessments of individual aspects of care remain difficult we can note that our audit is consistent with best practice as per current recommendations from the National Institute for Health and Clinical Excellence (NICE) and propose (additional) economic evaluations in future audits.[31,32]

Conflict of interest statement

No conflict of interest declared.

References

[1]. Goldhill DR, White SA, Sumner A. Physiological values and procedures in the 24 hours before ICU admission from the ward. Anaesthesia 1999;54:529–34.
[2]. Goldhill DR, Worthington L, Mulcahy A, Tarling M, Sumner A. The patient-at-risk team: identifying and managing seriously ill ward patients. Anaesthesia 1999;54:853–60.
[3]. Smith AF, Wood J. Can some in-hospital cardio-pulmonary arrests be prevented? A prospective survey. Resuscitation 1998;37:133–7.
[4]. Schein RM, Hazday N, Pena M, Rube BH, Sprung CL. Clinical antecedents to in-hospital cardiopulmonary arrest. Chest 1990;98:1388–92.
[5]. McGloin H, Adam SK, Singer M. Unexpected deaths and referrals to intensive care of patient on general wards. Are some cases potentially avoidable? J R Coll Physicians London 1999;33:255–9.
[6]. McQuillan P, Pilkington S, Allan A, et al. Confidential inquiry into quality of care before admission to intensive care. BMJ 1998;316:1853–8.
[7]. Morgan RJM, Williams F, Wright MM. An early warning scoring system for detecting developing critical illness. Clin Int Care 1997;8:100.
[8]. Stenhouse C, Coates S, Tivey M, Allsop P, Parker T. Prospective evaluation of a modified Early Warning Score to aid earlier detection of patients developing critical illness on a general surgical ward. Br J Anaesthesia 2000;84:663P.
[9]. Goldhill DR, McNarry AF. Physiological abnormalities in early warning scores are related to mortality in adult in-patients. Br J Anaesthesia 2004;92:882–4.
[10]. Goldhill DR, McNarry AF, Mandersloot G, McGinley A. A physiologically based early warning score for ward patients: the association between score and outcome. Anaesthesia 2005;60:547–53.
[11]. Cullinane M, Findlay G, Hargraves C, Lucas S. An acute problem. London: National Confidential Enquiry into Patient Outcome and Death (NCEPOD); 2005.
[12]. Audit Commission. Critical to success: the place of efficient and effective critical care services within the acute hospital. London: Audit Commission; 1999.
[13]. Department of Health. Comprehensive critical care: a review of adult critical care services. London: Department of Health; 2000.
[14]. Franklin C, Matew J. Developing strategies to prevent in-hospital cardiac arrest: analysing responses of physician and nurses in the hours before the event. Crit Care Med 1994;22:244–7.
[15]. Goldhill DR, Worthington L, Mulcahy A, Tarling M, Sumner A. The patient at risk team: identifying and managing seriously ill ward patients. Anaesthesia 1999;54:853–60.
[16]. Intensive Care National Audit and Research Council (ICNARC) https://www.icnarc.org [accessed October 2009].
[17]. Sandroni C, Nolan J, Cavallaro F, Antonelli M. In-hospital cardiac arrest: incidence, prognosis and possible measures to improve survival. Intensive Care Med 2007;33:237–45.
[18]. Peberdy M, Ornato JP, Larkin GL, et al. Survival from in-hospital cardiac arrest during nights and weekends. JAMA 2008;299:785–92.
[19]. Newcastle upon Tyne Hospitals NHS Foundation Trust, Clinical Audit Report 2005.
[20]. Harrison DA, Parry GJ, Carpenter JR, Short A, Rowan K. A new risk prediction model for critical care: The Intensive Care National Audit & Research Centre (ICNARC) model. Crit Care Med 2007;35:1091–8.
[21]. Bellomo R, Goldsmith D, Uchino S, et al. Prospective controlled trial of effect of a medical emergency team on postoperative morbidity and mortality rates. Crit Care Med 2004;32:916–21.
[22]. Buist MD, Moore GE, Bernard, et al. Effects of a medical emergency team on reduction of incidence and mortality from unexpected cardiac arrest in hospital: preliminary study. BMJ 2002;324:387–90.
[23]. Priestley G, Watson W, Rashidian A, et al. Introducing critical care outreach: a ward-randomized trial of phased introduction in a general hospital. Intensive Care Med 2004;30:1398–404.
[24]. Mitchell IA, McKay H, Van Leuvan C, et al. A prospective controlled trial of the effect of a multi-faceted intervention on early recognition and intervention in deteriorating hospital patients. Resuscitation 2010;81:658–66.
[25]. Hillman K, Chen J, Creitkos, et al. Introduction of the medical emergency team (MET) system. A cluster randomised controlled trial. Lancet 2005;365:2091–7.
[26]. Fletcher SJ, Cuthbertson BH. Outreach, epistemology and the evolution of critical care. Anaesthesia 2010;65:115–8.
[27]. Price RJ, Cuthbertson BH, Cairns CJ. The findings of the International Conference on Medical Emergency Teams are biased and misleading. Crit Care Med 2007;35:992–3.
[28]. CHKS. www.chks.co.uk [accessed May 2010].
[29]. Improving intensive care outcomes with ward-based consultant physicians and MEWS charts, in patients admitted to intensive care from a hospital's renal unit. British Renal Society and Renal Association, Joint Annual Conference, May 2010.
[30]. National Cardiac Arrest Audit. Healthcare Quality Improvement Partnership. http://www.hqip.org.uk/national-cardiac-arrest-audit-ncaa-2 [accessed June 2010].
[31]. Briggs A, Schulpher M. Commentary: Markov models of medical prognosis. BMJ 1997;314:354.
[32]. National Institute for Health and Clinical Excellence. Monitoring patients in hospital and caring for them if their health becomes worse. London: NICE Clinical Guideline 50; July 2007.