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Simulation and education

Regular in-situ simulation training of paediatric Medical Emergency Team leads to sustained improvements in hospital response to deteriorating patients, improved outcomes in intensive care and financial savings☆

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ABSTRACT

Aim of the study: The introduction of a paediatric Medical Emergency Team (pMET) was accompanied by weekly in-situ simulation team training. Key ward staff participated in team training, focusing on recognition of the deteriorating child, teamwork and early involvement of senior staff. Following an earlier study [1], this investigation aimed to evaluate the long-term impact of ongoing regular team training on hospital response to deteriorating ward patients, patient outcome and financial implications.
Methods: Prospective cohort study of all deteriorating in-patients in a tertiary paediatric hospital requiring admission to paediatric intensive care (PICU) the year before, 1 year after and 3 years after the introduction of pMET and team training.
Results: Deteriorating patients were recognised more promptly (before/1 year after/3years after pMET; median time 4/1.5/0.5 h, $p < 0.001$), more often reviewed by consultants (45%/76%/81%, $p < 0.001$) and more rapidly escalated to PICU (median time 10.5/5/3.5 h, $p = 0.02$). There was a significant reduction in associated PICU admissions (56/51/32, $p = 0.02$) and PICU bed days (527/336/193, $p < 0.001$). The total annual cost of training (£74,250) was more than offset by savings from reduced PICU bed days (£801,600 per annum). Introduction of pMET coincided with significantly reduced hospital mortality ($p < 0.001$).
Conclusion: These results indicate that lessons learnt by ward staff during team training led to sustained improvements in the hospital response to critically deteriorating in-patients, significantly improved patient outcomes and substantial savings. Integration of regular in-situ simulation training of medical emergency teams, including key ward staff, in routine clinical care has potential application in all acute specialties.

1 Introduction

Response to deteriorating patients is critically important for patient safety and a significant marker of quality of care.

Professional efforts to improve this response have focused on the recognition of patient deterioration (afferent limb) and the subsequent escalation of care, often involving Medical Emergency Teams (MET; efferent limb). Recent publications highlight the importance of human factors and ward culture for effective escalation of care. Communication limited by intra- and inter-professional hierarchies, ineffective team leadership and expectations of an adverse response by senior staff following activation of escalation procedures were identified as barriers [2,3], whereas an explicit "permission to act" for clinical staff appeared to facilitate effective escalation [4].

Staff empowerment was described as a factor which increasingly enabled ward staff to activate medical emergency teams in a maturing MET system [5]. Institutional changes in response to deteriorating patients include a cultural shift which needs time to develop [6] and evaluation of such changes should include long-term studies.

External courses have changed in recent years to include training in team leadership and effective communication [7]. However,

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recent surveys of US and UK paediatric hospitals [10,11] confirmed there is little evidence institutions focus on regular in-situ training of medical emergency teams or ward staff dealing with deteriorating patients [8,9]. The costs associated with long-term in-situ training programmes may have been a barrier to their establishment. A cost benefit analysis, identified as an important topic for research [12,13], should include consideration of additional costs to health care providers due to failings in the rescue of deteriorating patients [14].

An earlier study reported on the introduction of weekly in-situ simulation training for pMET [1]. Registrars and senior nurses from all hospital wards were included in team training on a rotational basis, thereby exposing key decision makers on hospital wards to regular training in the recognition and management of deteriorating patients. Review of unplanned in-house admissions to PICU demonstrated a significantly accelerated response to patient deterioration, a trend towards fewer unplanned PICU admissions and improved PICU outcomes.

This study aimed to evaluate:

- whether the improvements in hospital response to evolving critical illness and subsequent patient outcome were sustained 3 years after the start of regular team training.
- the financial implications of team training and potential cost benefits.

2 Methods

All unplanned admissions of paediatric in-patients to the Paediatric Intensive Care Unit (PICU) were prospectively audited for three 1 year periods: 1 year before; 1 year after; and 3 years after introduction of pMET and weekly ongoing team training.

Patient deterioration was defined as a breach of physiological criteria or documented staff concerns (local adaptation of previously published criteria) [15]. Time from onset of patient deterioration to first staff response and time from first staff response to PICU admission were recorded. Actions categorised as staff response were prospectively identified to analyse ward management of evolving critical illness: increased frequency of nursing observations; medical review including seniority of reviewer; patient transfer to high dependency care prior to PICU admission. Outcomes in intensive care included severity of illness at PICU admission (PIM2 score) [16]; length of PICU stay; PICU mortality.

Depending on the time of onset of patient deterioration: normal working hours, Monday to Friday 9 am to 5 pm, versus all other hours of the week, further analysis was undertaken to demonstrate any impact of ward staffing and changes to staffing over time. Supported by NHS Lothian finance department, costs for team training were calculated; any savings generated as a result of enhanced training were calculated based on recently published UK data for costs of paediatric intensive care beds [17,18].

2.1 Study design

The multi-disciplinary paediatric pMET had an extended remit to respond to physiological deterioration, staff concerns and resuscitation calls. Team availability was around the clock; team composition was six medical and nursing staff from Emergency Medicine (1), PICU (2), and paediatric wards (3).

Simultaneously, weekly team training was started. All team members attended training on a rotational basis, resulting in four to ten attendances per year. During training, team members assumed the same roles as in clinical practice. Training, initially provided in a clinical skills setting, moved increasingly into clinical areas (medical and surgical wards, emergency department). Medium fidelity paediatric (Laerdal MegaCode Kid Vital Sim Advanced) and infant (Laerdal ALS Baby) manikins were used.

Two trainers, one consultant and one senior nurse, facilitated each training session. All trainers were senior staff from different departments of our institution: PICU, Emergency Medicine, Medical Paediatrics, Paediatric Anaesthesia and Resuscitation Training. Regular reviews of pMET calls and unplanned PICU admissions were used to identify topics for team training. Scenarios included deteriorating medical and surgical patients in paediatric wards and in the Emergency Department, paediatric trauma and adult visitors; each training session lasted 2 h.

Debriefing focused on: a supportive attitude towards ward staff; recognition of the deteriorating child; role allocation and communication within the team; early involvement of senior staff; early liaison with paediatric intensive care.

Time for training was protected, resulting in attendance rates of >95%. The study was approved by the hospital quality improvement team and did not require individual patient consent. 25% of case notes were randomly selected for review by a second examiner to assess inter-rater variability. Statistical analysis included Chi Square test, Kruskal-Wallis test, Mann-Whitney *U* test and Anova test to detect statistical significance ($p < 0.05$; IBM SPSS Statistics 22 (2013)). Confidence intervals were calculated using "Confidence Interval Analysis Version 2.1.2.". There was no significant difference in age and gender distribution over the 3 study periods (ANOVA, $p = 0.90$).

3 Results

3.1 Ward management of deteriorating in-patients with evolving critical illness

Changes from year pre pMET to year 1 post pMET implementation:

Hospital response to deteriorating ward patients, as detailed in Table 1 and fully discussed in a previous publication [1], improved significantly from the year pre pMET to year 1 after pMET implementation. The number of deteriorating ward patients requiring PICU admission did not change significantly.

Changes from year 1 to year 3 post pMET implementation:

There was further significant improvement in the early response to patient deterioration as demonstrated by the reduced time from patient deterioration to first staff response (Table 1). Subsequent aspects of the management of evolving critical illness, including consultant review and the time required to escalate support to PICU admission, showed consolidation of earlier improvements, but no further significant changes.

Analysing which factors triggered the first staff response to patient deterioration (Table 2), it is noticeable that the frequency in breaches of physiological criteria remained relatively constant. Staff concerns, however, were raised significantly more often in the third year.

The time of onset of patient deterioration was relevant for staff response. Significant further improvements from year 1 to year 3 post pMET implementation were only seen in the early staff response during the out-of-hours period. In year 3, the median time from patient deterioration to first staff response during the out-of-hours period equalled that observed during normal working hours (Table 3). The time for subsequent escalation to PICU continued to trend down during the out-of-hours period, however, it did not reach the low levels demonstrated during working hours. Impact of staffing and the role of team training will be considered in the discussion section.

The number of deteriorating ward patients requiring PICU admission reduced significantly over the entire study period

Table 1
Clinical management of deteriorating paediatric in-patients with evolving critical illness over three one-year periods.

Cohort	1 year pre pMET	1st year post pMET	3rd year post pMET	P-value
Hospital admissions	7854	8652	8444	
Number of unplanned PICU admissions	56	54	32	
Unplanned PICU admissions with earlier warning signs present	56	51	32	0.02 (0.32/0.05)
Response to patient deterioration (all patients)				
Time between patient deterioration and first staff response [a]	4 [1.1–10.4]	1.5 [0.5–4.5]	0.5 [0.0–1.9]	<0.001 * (<0.001/0.01)†
Increased frequency of nursing observations	35/56	42/51	25/32	0.09 (0.04/0.63)
Patient transfer to HDU	10/50	19/39	8/20	0.02 (0.004/0.52)
Consultant review	25/56	39/51	26/32	<0.001 (<0.001/0.96)
Time between first staff response and PICU admission [a]	10.5 [3.3–29.3]	5 [2.0–14.0]	3.5 [2.1–14.9]	0.02 * (0.02/0.59)†
Response to patient deterioration (pMET not involved)				
Time between patient deterioration and first staff response [a]	4 [1.1–10.4]	1 [0.5–4.8]	0.5 [0.0–2.1]	<0.001 * (<0.001/0.02)†
Increased frequency of nursing observations	34/53	35/43	23/30	0.15 (0.06/0.62)
Patient transfer to HDU	10/47	16/32	8/18	0.02 (0.01/0.71)
Consultant review	23/53	34/43	25/30	<0.001 (<0.001/0.65)
Time between first staff response and PICU admission [a]	11 [3.7–29.3]	7 [2.0–12.1]	4 [2.4–15.5]	0.01 * (0.02–0.74)†

[a] Median time in hours [25th + 75th centiles in square brackets]; * Kruskal-Wallis test, † Mann- Whitney *U* test, all other: Chi Square test; p values relate to change over entire observation period, p values in brackets relate to change from year pre pMET to 1st year post pMET/1st year post pMET to 3rd year post pMET; reduced denominator in "Patient transfer to HDU" as some patients were already on HDU at the time of patient deterioration.

Table 2
Factors which triggered first response to patient deterioration.

Cohort	1 year pre pMET	1st year post pMET	3rd year post pMET	P-value
Number of unplanned PICU admissions	56	51	32	
Staff concerns	26	28	25	0.02(0.38/0.03)
Low O2 saturations	30	34	20	0.37(0.17/0.70)
Increased work of breathing	37	30	17	0.47(0.44/0.61)
Tachypnoea	20	16	12	0.83(0.63/0.57)
Tachycardia	33	27	20	0.67(0.53/0.39)
Airway threat	11	7	4	0.59(0.67/0.87)
Neurological deterioration	5	7	5	0.60(0.43/0.81)
Low GCS	6	4	2	0.75(0.61/0.79)

Main p value relates to change over all three 1-year periods; P values in brackets relate to change from year pre pMET to 1st year post pMET/1st year post pMET to 3rd year post pMET; all Chi Square test.

(Table 1); interestingly, the main reduction occurred in patients who started to deteriorate out-of-hours (Table 3).

The majority of unplanned PICU admissions continued to be admitted without involvement of pMET (53/56 vs. 40/51 vs. 30/32). The earlier improvements to deteriorating ward patients were sustained or showed further significant improvements in year 3, even if pMET was not involved at any stage (Table 1).

Second review of 25% of cases demonstrated a high level of inter-rater agreement of at least 89% in all parameters.

3.2 Patient outcome in paediatric intensive care and hospital mortality

There was a significant reduction in the number of unplanned PICU admissions from deteriorating ward patients over the entire study period (Table 4). The number of related PICU bed days significantly reduced year on year. There was a trend towards reduced severity of illness on PICU admission (PIM2 score) and reduced average length of PICU stay (9.9/7.8/6.4 days). There was a trend towards reduced PICU mortality (7/53 vs. 2/43 vs. 2/30).

A significant reduction in overall hospital mortality co-incided with the introduction of pMET and team training ($p < 0.001$, Chi Square test; Fig. 1).

3.3 Financial implications of team training

Costs for training included staffing for the multi-disciplinary faculty (£ 46,800 per annum (pa): preparation of training sessions, 48 two-hourly core training sessions, faculty meetings, review of pMET calls and unplanned PICU admissions, administrative support), protected training time for attendees (£17,450 pa), consumables and maintenance of manikins (£10,000 pa), resulting in a total cost for training of £74,250 pa. Previously acquired medium fidelity paediatric manikins were used (original costs:

Table 3
Clinical management of deteriorating paediatric in-patients with evolving critical illness and time of onset of patient deterioration.

Cohort	1 year pre pMET		1 st year post pMET		3rd year post pMET		P-value	
Hospital admissions	7854		8652		8444			
Time of onset of deterioration	wwh	ooh	wwh	ooh	wwh	ooh	wwh	ooh
Unplanned PICU admissions with earlier warning signs present	18	38	21	30	14	18	0.51 (0.85/0.27)	0.01 (0.17/0.10)
Response to deteriorating patients								
Time between patient deterioration and first staff response *	3 [0.9–15.5]	4 [1.8–10.1]	1 [0.5–4.3]	2 [0.5–5.1]	0.5 [0.0–1.5]	0.5 [0.0–2.1]	<0.006 * (0.04/0.19) †	<0.001 * (0.03/0.04) †
Increased frequency of observations	11/18	24/38	19/21	23/30	12/14	13/18	Not done (0.07/0.91)Y	0.47 (0.23/0.73)Y
Patient transfer to HDU	4/17	6/33	9/19	10/20	2/9	6/11	Not done (0.78/0.88)Y	0.02 (0.01/0.81)
Consultant review	5/18	20/38	18/21	21/30	12/14	14/18	Not done (<0.001/0.62)Y	0.13 (0.15/0.56)
Time between first staff response and PICU admission *	12 [3.1–31.4]	10.75 [1.9–24.4]	3.5 [1.8–20]	7.75 [0.6–12.9]	2.8 [2–6.5]	6 [0.0–17.5]	0.16 * (0.25/0.43) †	0.15 * (0.67/0.88) †

Onset of deterioration: within working hours (wwh; Monday to Friday 09:00 tom 17:00) or out-of-hours (ooh, all other times); [a] Median time in hours [25th and 75th centiles in square brackets]; main p values relate to change over entire observation period – not done when numbers were too small in some categories; p values in brackets relate to change from year pre pMET to 1st year post pMET/1st year post pMET to 3rd year post pMET; * Kruskal-Wallis Test; † Mann- Whitney *U* test; all other tests: Chi Square test; Y indicates Yates correction; reduced denominator in "Patient transfer to HDU" caused by some patients already on HDU at time of deterioration.

Table 4
PICU outcomes of deteriorating paediatric in-patients with warning signs of evolving critical illness.

Cohort	1 year Pre pMET	1 year post pMET	3 years post pMET	P-value
Hospital admissions	7854	8652	8444	
Unplanned PICU admissions with earlier warning signs present	56	51	32	0.02 (0.33/0.05)
Related PICU bed days	527	336	193	<0.001 (<0.001/<0.001)
Total PICU bed days (all admissions)	2142	1901	1826	
PIM2 score [a]	0.040 [0.01/0.06]	0.029 [0.008/0.06]	0.020 [0.01/0.06]	0.64* (0.38/0.93)†
PICU mortality	7	2	2	0.30 (0.15/0.71)

*Kruskal-Wallis test, † Mann- Whitney *U* test, all other: Chi Square test; main p values relate to change over entire observation period, p values in brackets relate to change from year pre pMET to 1st year post pMET/1st year post pMET to 3rd year post pMET; [a] Median PIM2 score [25th + 75th centiles in square brackets].

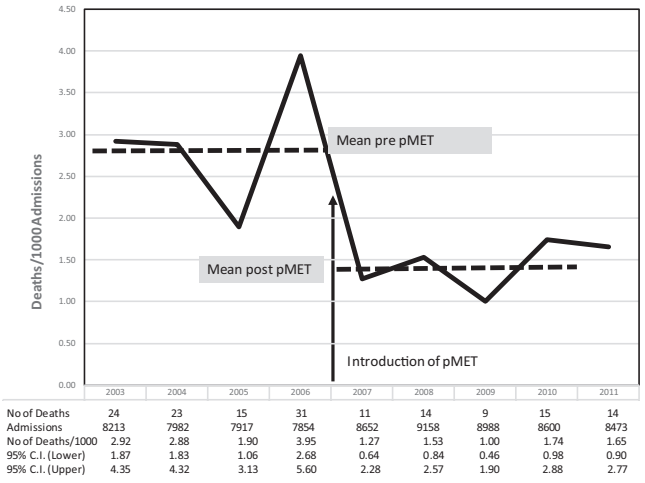

Fig. 1. Number of hospital admissions and hospital deaths at RHSC Edinburgh 2003–2011. Note: Deaths in the emergency department (ED) are not included; mean hospital mortality pre pMET = 2.9/1000 admissions, post pMET = 1.4/1000 admissions; Fischer's Exact test (2-tailed) p < 0.001.

£6200; today's costs including monitor and tablet: £9200).There were no additional capital costs.

As demonstrated, the number of PICU bed days associated with unplanned admissions from deteriorating ward patients reduced significantly. Using the average of recently published data for costs of paediatric intensive care beds in the UK [17,18], this equated to a reduction of associated costs by £801,600 pa (334 PICU bed days *£2400).

4 Discussion

4.1 Response to deteriorating patients at ward level and patient outcome

This study demonstrated sustained significant improvement in ward response to deteriorating in-patients following introduction of a paediatric MET with weekly ongoing in-situ team training. The improved response was not limited to cases where pMET was directly involved, but also demonstrable in the majority of unplanned intensive care admissions without pMET attendance. Team training regularly exposed all ward-based decision makers to recognition and management of the deteriorating child, suggesting that lessons learnt during team training were applied to all deteriorating ward patients with evolving critical illness.

In addition to earlier improvements [1], this study demonstrated further significant reduction in the time from patient deteriora-

tion to first staff response; staff concerns were significantly more often the trigger for early escalation, suggesting empowerment of ward staff. Over the entire study period, the number of deteriorating ward patients requiring subsequent PICU admission reduced significantly. A significant reduction in hospital mortality, which co-incided with the introduction of pMET and team training, was sustained.

4.2 Importance of team training and human factors

Human factors are principal contributors to suboptimal outcomes in health care, particularly when multi-disciplinary teams face challenging situations in communication and teamwork under pressure [19]. By integrating key medical and nursing ward staff into pMET and team training, the management of evolving critical illness ceased to be the exclusive provenance of specialist critical care and emergency medicine expertise. This is in accordance with literature recommendations to integrate team training and crisis resource management into routine clinical care, allowing ongoing education and skill sharing [20,21].

The changes observed in this study cannot be a direct effect of actions only by pMET as significant improvements remained demonstrable even if the team was not involved at any stage. All changes were in keeping with practice taught at team training: focus on early response to physiological deterioration and concerns; early involvement of senior staff across traditional departmental boundaries; early escalation to PICU care.

In the third year after introduction of pMET training, significant improvements in the early response to deterioration stand out. This aspect is primarily dependant on junior ward staff, a staff group which frequently reported barriers to escalation in the literature [22]. Barriers identified were experience or expectations of an adverse response by senior staff to raising concerns and to initiating escalation or the impression that ward staff "should have been able to cope independently" [3,23]. Interestingly, "subjective" staff concerns were, in contrast to "objective" physiological breach criteria, significantly more often the trigger for escalation in the third year. This suggests that lessons learnt by more senior staff during team training were increasingly adopted by more junior ward staff, following observed positive responses to earlier advanced escalation, reinforcing this shifting culture within our institution. This is consistent with recent publications describing more frequent escalation of care based on staff concerns in maturing response systems [5]. The explicit "permission to act" and awareness that staff escalating care are backed by the organisation have been reported as factors which help to overcome barriers to escalation [4].

In addition to reasons identified earlier [1], four factors appear to have had particular importance for the demonstrated improvements:

- Training faculty: consultants from all major hospital departments are part of the training faculty, bringing clinical credibility and local knowledge to the training, attributes previously described as first priorities when trying to institute and sustain change in a clinical environment [24,25]. Participants are reassured that responses adopted from team training (e.g. asking a non-resident consultant to attend out-of-hours) will be supported by senior staff when applied in clinical practice. Additionally, consultant trainers act as ambassadors for the training programme within their own departments, increasing acceptance of practices/attitudes taught during training. Consequently, and in contrast to other quality improvement initiatives [4], medical staff were equally as engaged as nursing staff.
- Regularity of training: Infrequent training of individuals carries the risk of producing a sub-threshold learning effect which will not lead to sustained change of practice [26]. This observation is consistent with a recent systematic review of the effectiveness of education in the recognition and management of deteriorating patients: an intervention with a single study day for staff did not lead to changes in clinical outcomes, however, there were significant differences when training was provided on a regular basis [10].
- Feedback loop: Learning points from reviews of unplanned admissions to PICU and pMET calls are incorporated into subsequent team training sessions, allowing focus on factors relevant to local practice. This is in keeping with studies recommending that simulation educators make best use of real patient information to guide the content of simulation training [27] and to identify latent safety threats [28,29].
- Building relationships: medical emergency teams are described as loosely coupled due to the daily changing team composition, leaving team members little opportunity to develop team skills or relationships [30]. Interestingly, comments from training participants suggest they not only learned about the team approach to patient deterioration, but also used team training as an opportunity to build trust and reciprocity with staff from different departments. Improving relationships as a social return of investment has been described as an underused and undervalued concept in the literature [31].

A systematic review of early warning systems and emergency response teams concluded that the sustainability of either approach was dependent on continued review of the activation process and an associated ongoing education programme [32]. The results from this study, which identified significant changes in clinical practice and patient outcome, thereby fulfilling level 3 and 4 in the Kirkpatrick model of evaluation of training programmes [33], support this conclusion.

4.3 Cost/benefit analysis

To our knowledge, this is the first study to report a significant return from investment in regular in-situ simulation training of a multi-disciplinary Medical Emergency Team. Savings from the associated costs of PICU bed days substantially exceeded the costs of regular team training. The calculated savings are likely to provide a conservative estimate as it is reasonable to assume that patients with a lower severity of illness score on PICU admission and a reduced length of PICU stay would also have a shorter subsequent hospital stay; however, this study did not include post-PICU outcomes.

A recent systematic review found that few studies on in-situ simulation training provide return of investment information, but several small trials have demonstrated return of investment from specific training interventions for individual practice [34–36]. Associated savings due to reduced institutional insurance premiums have been reported in hospitals establishing simulation team training for high risk areas of medicine (obstetrics, anaesthesia) [37]. Failing to rescue deteriorating patients has been demonstrated to incur substantial additional costs for health care providers [38]; conversely, improving response to evolving critical illness, as demonstrated in this study, is likely to carry significant financial benefits.

5 Limitations

This observational cohort study cannot inform directly on cause and effect, as many uncontrolled variables may have had an effect on outcome. It is therefore not possible to conclude that the improved response to deteriorating ward patients caused the reduction in hospital mortality. The relatively small sample size and

low underlying mortality rate in paediatric intensive care limited the ability to detect significant differences in PICU mortality.

During the first year following pMET introduction, medical paediatrics moved to a consultant of the week system, with a consultant paediatrician available at all times during working hours. This change probably contributed to the increase of consultants reviewing deteriorating patients during working hours, but is unlikely to have influenced the significant improvements in early ward response before consultant involvement. Additionally, there were significant improvements in the out-of-hours response in year 1 post pMET with no changes to the out-of-hours service cover.

Between year 1 post pMET and year 3 post pMET, the seniority of the out-of-hours resident medical paediatric cover increased to senior registrar level. There was subsequently no significant change in the late response to patient deterioration out-of-hours (when these more senior doctors became involved), but significant improvements in the early response by more junior ward staff (and no changes to junior staffing), suggesting an impact of team training. It therefore seems reasonable to conclude that regular team training made a major contribution to the documented clinical and financial benefits. Further studies in adult cohorts are merited.

6 Conclusions

Weekly in-situ team training for a paediatric Medical Emergency Team, with an emphasis on recognition of the deteriorating child, communication, teamwork and early involvement of senior staff, resulted in improved response by ward staff to evolving critical illness and improved patient outcome in intensive care. Costs associated with the introduction and maintenance of the training programme were more than offset by a significant reduction in the number of associated intensive care bed days. Improvements were maintained or enhanced over a three-year period. Integration of regular in-situ simulation team training has the potential to offer sustainable improvements beyond paediatrics and merits further evaluation in a larger patient population.

Conflict of interest

None.

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