Financial consequences of the implementation of a rapid response system on a surgical ward

Friede Simmes RN MScN,1 Lisette Schoonhoven RN, PhD,3,4 Joke Mintjes PhD,2 Eddy Adang PhD5 and Johannes G. van der Hoeven MD PhD6

1Lecturer and Researcher, 2Emeritus Health Care Professor, Faculty of Health and Social Studies, HAN University of Applied Sciences, Nijmegen, The Netherlands
3Senior Research Fellow Nursing Science, Scientific Institute for Quality of Healthcare, Radboud University Medical Centre, Nijmegen, The Netherlands
4Associate Professor, Faculty of Health Sciences, University of Southampton, Southampton, UK
5Senior Economist, Department Epidemiology, Biostatistics and HTA, Radboud University Medical Centre, Nijmegen, The Netherlands
6Professor of Intensive Care, Department of Intensive Care Medicine, Radboud University Medical Centre, Nijmegen, The Netherlands

Keywords
Financial analysis, general surgery, inpatients, intensive care units, medical emergency team, rapid response system

Abstract

Rationale, aims and objectives Rapid response systems (RRSs) are recommended by the Institute for Healthcare Improvement and implemented worldwide. Our study on the effects of an RRS showed a non-significant decrease in cardiac arrest and/or unexpected death from 0.5% to 0.25%. Unplanned intensive care unit (ICU) admissions increased significantly from 2.5% to 4.2% without a decrease in APACHE II scores. In this study, we estimated the mean costs of an RRS per patient day and tested the hypothesis that admitting less severely ill patients to the ICU reduces costs.

Methods A cost analysis of an RRS on a surgical ward, including costs for implementation, a 1-day training programme for nurses, nursing time for extra vital signs observation, medical emergency team (MET) consults and differences in unplanned ICU days before and after RRS implementation. To test the hypothesis, we performed a scenario analysis with a mean APACHE II score of 14 points instead of the empirical 17.6 points for the unplanned ICU admissions, including 33% extra MET consults and 22% extra unplanned ICU admissions.

Results Mean RRS costs were €26.87 per patient-day: implementation €0.33 (1%), training €0.90 (3%), nursing time spent on extended observation of vital signs €2.20 (8%), MET consults €0.57 (2%) and increased number of unplanned ICU days after RRS implementation €22.87 (85%). In the scenario analysis mean costs per patient-day were €10.18.

Conclusions The costs for extra unplanned ICU days were relatively high but the remaining RRS costs were relatively low. The ‘APACHE II 14’ scenario confirmed the hypothesis that costs for the number of unplanned ICU days can be reduced if less severely ill patients are referred to the ICU. Based upon these findings, our hospital stimulates earlier referral to the ICU, although further implementation strategies are needed to achieve these aims.

Introduction

Patients often show deteriorating vital signs for hours or even days before ending in cardiac arrest or unexpected hospital death [1]. Timely stabilization of vital functions may prevent this. For this purpose, rapid response systems (RRSs) were introduced. These systems aim to identify and treat at-risk patients at an adequate level of care during the early phase of deterioration and include the availability of a rapid response team (RRT) to support the ward team [2]. The RRS is highly recommended by the Institute for Healthcare Improvement [3,4] and implemented in many countries. Proceedings of the first international consensus conference on medical emergency teams (METs) claimed an outcome benefit of RRSs not only including reduction in cardiac arrests and unexpected deaths but also in intensive care unit (ICU) and hospital length of stay (LOS) and lower costs [2].

Our study on the effects of an RRS showed a non-significant decrease in cardiac arrest and/or unexpected death from 0.5% to 0.25% [5]. These results are in line with many other studies [6–11]. However, our study showed a significant increase in the number of unplanned ICU admissions after implementation (2.5% to 4.2%), without a decrease in severity of illness (mean APACHE II
score 17.5 versus 17.6) and median ICU LOS (3.5 days versus 3 days, P = 0.94) [5]. These results are in line with the studies of Buist et al. [12] and Karpman et al. [13]. Furthermore, in our study, hospital LOS was unchanged [5]. Information on APACHE II scores and ICU/hospital LOS, in addition to the number of (un)planned ICU admissions, are rarely reported in studies on the effect of an RRS. These outcomes are of influence on hospital costs. Until now, the impact of an RRS on hospital costs has not been studied. Insight in these hospital costs is critical to justify widespread implementation of RRSs.

The aim of this study was to estimate the costs of an RRS. Firstly, we determined the mean costs of the RRS per patient-day. Secondly, by means of a scenario analysis, we explored the hypothesis that an increased number of unplanned ICU admissions with less severely ill patients results in a reduction of the RRS costs per patient-day.

### Methods

The need for informed consent was waived by the Medical Ethics Committee of district Arnhem-Nijmegen, CMO-nr.: 2005/310. We compared costs before and after RRS implementation. For this, we used data from our before-after study published previously [5]. In brief, the before study (period 1) was conducted for 1 year, the after study (period 2) for 2 years. The RRS was implemented for 4 months. We included patients who stayed in the surgical ward for ≥72 hours after major general surgery. There were 1376 patients in period 1 and 2410 patients in period 2.

Before introduction of the RRS, consultation of a doctor after observing abnormal vital signs was left to the discretion of the attending nurse. Vital signs were not routinely recorded three times daily, and oxygen saturation and respiratory rate were not included in the standard observation protocol. The RRS included the introduction of a MET and the use of a single-parameter track and trigger system. The MET was a doctor-led team including an intensivist and a critical care nurse and was accessible 24/7. We used a 2-tiered MET calling procedure. In the first tier, nurses were expected to observe the patient with the use of the early warning score (EWS) at least three times daily. Nurses called the ward doctor immediately if one of the EWS criteria was met, that is, respiratory rate <8 or >30 per minute, oxygen saturation <90%, systolic blood pressure <90 or >200 mm Hg, heart rate <40 or >130 per minute, a decrease of two points in the eye, motor, verbal score, or if the nurse felt worried about the patient’s condition [12]. The ward doctor had to evaluate the patient at the bedside within 10 minutes. In the second tier, the ward doctors activated the MET immediately if a serious situation existed or if the patient did not stabilize after an initial intervention.

### Cost analysis

The analysis was performed from a health care perspective where only direct medical costs related to the RRS were included. All unit costs were converted to 2009 prices using the Dutch consumer price index, statistics Netherlands [14]. Prices for personnel and ICU costs were retrieved from the Dutch guideline for cost analyses in health care [15].

### Mean RRS costs per patient-day

We categorized the costs of an RRS into costs for implementation and maintenance, training, nursing time spent on extended observations of vital signs, MET consults, and differences in the number of unplanned ICU days before and after RRS implementation. Difference in hospital LOS was not included in this calculation as this indicator did not change after RRS implementation [median 7, interquartile range (IQR) 5–13 versus median 7, IQR 5–13] [5]. A patient-day was defined as a day in the hospital, including the day of admission and discharge. An unplanned ICU day was defined as a day in the ICU caused by an unplanned ICU admission from the surgical ward, including the day of admission and discharge.

### Costs

Table 1 shows the RRS implementation and maintenance costs made for the surgical ward. For a specification of these costs, see Table 2. Table 3 shows a specification of the training costs. Table 4 shows the nursing time spent on extended observations of vital signs per admitted patient. These costs were based upon differences in the daily observation time in periods 1 and 2. To assess the nursing time needed to observe patients’ vital signs, we observed four nurses during vital sign measurements in 16 patients.

---

### Table 1. RRS implementation and maintenance costs surgical ward*

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Total No. of wards</th>
<th>Costs surgical ward † (€)</th>
<th>Costs spread over 10 years = per year ‡ (€)</th>
<th>Surgical ward costs 2 years § (€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructing of an implementation plan</td>
<td>7 496</td>
<td>268</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>Extra materials ICU</td>
<td>22 889</td>
<td>3270</td>
<td>327</td>
<td>654</td>
</tr>
<tr>
<td>Extra materials surgical ward</td>
<td>9 760</td>
<td>976</td>
<td>1952</td>
<td></td>
</tr>
<tr>
<td>RRS coordination surgical ward, yearly</td>
<td>1 568</td>
<td>3136</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RRS continuation surgical ward, yearly</td>
<td>2 050</td>
<td>4100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>9896</td>
</tr>
</tbody>
</table>

*For specification, see Table 2.
†Costs were made for the benefit of 28 wards.
‡One-off costs were spread over 10 years.
§Patients were included during a period of 2 years.

ICU, intensive care unit; RRS, rapid response system.
The cost of one MET consult was €129.50; 1 hour for an intensivist (€103 per patient-related hour) and 0.75 hour for an intensive care nurse (€30.50 per hour).

The costs of an ICU day and ward day included costs for medical specialists, nurses, material, food and hotel facilities, drugs, housing, overhead and equipment [15]. The extra costs for an ICU day were €1608; calculated as daily ICU costs minus daily ward costs (€2183 – €575). Mean hospital costs per patient-day concerned the mean of the daily ward costs and daily unplanned ICU day costs.

Table 5 shows the formulas for the calculation of the differences in the mean costs per patient-day before and after RR implementation. Differences in unplanned ICU days were based upon the ratio of unplanned ICU days per 1000 hospital days before and after RRS implementation (0.12 versus 0.26, respectively).

‘APACHE II 14’ scenario

In our effect study, we found a mean APACHE II score of 17.6 for unplanned ICU admission [5]. Since we found an absent or delayed MET consult in 50% prior to an adverse event, we expect that it will be possible to increase the MET consults making earlier ICU referrals possible. In the scenario analysis, we hypothetically lowered the mean APACHE II score to 14. For this, a Monte Carlo simulation approach was used. This method randomly draws APACHE II scores from a distribution based upon a preset mean of 14 and a standard deviation (SD) set on 6.1, based upon the SD found in our effect study [5]. The APACHE II score range was set from 0 to 48; this range and the ICU LOS per APACHE score were derived from the hospital ICU database, period 2004–2011. Subsequently, the ICU LOS for each of the 10 000 simulated APACHE II scores was added into the database. This provides a mean ICU-LOS with SD based upon a mean APACHE II score of 14.

We assumed that to achieve a mean APACHE II 14 score for unplanned ICU admissions from the ward, ICU referral by the MET should occur in 80% of the consulted patients instead of 60% found in our effect study [5]. Our effect study shows that 65 of the 100 unplanned ICU admissions were preceded by a MET consult.

We therefore added 22 (22%) unplanned ICU admissions (80/60 × 65) to the empirical number of 100 unplanned ICU admissions. Furthermore, in the optimal situation, the MET should be
consulted in all patients prior to the unplanned ICU admission from the ward. In our effect study, 35 of the 100 unplanned ICU referrals were without prior MET consult(s). As mentioned before, we assumed that in 80% of the MET consults, the patient should be referred to the ICU. This would result in 44 (33%) extra MET consults (35/0.8) in addition to the 134/2410 empirical MET consults (73 MET consults per 1000 admissions in the ‘APACHE II 14’ scenario compared to the empirical 56 MET consults per 1000 admissions).

### Results

Mean RRS costs were €26.87 per patient-day; implementation and maintenance €0.33 (1%), training €0.90 (3%), nursing time €2.20 (8%), MET consults €0.57 (2%) and extra unplanned ICU days €22.87 (85%).

Mean hospital costs per patient-day were €594. Costs increased with €26.87 to €621 (4.5%) after RRS implementation. In the ‘APACHE II 14’ scenario, we added one-third extra MET consults

<table>
<thead>
<tr>
<th>Table 4 Nursing time spent on observation vital signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations P1</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>1st and 2nd day after surgery</td>
</tr>
<tr>
<td>10.6 other days</td>
</tr>
<tr>
<td>1 time no observations</td>
</tr>
</tbody>
</table>

Nursing time in seconds per admission: 3284
Nursing time in hours per admission: 0.91

Observation included hand washing and transfer between patient rooms.

In period 1, systolic blood pressure and heart rate were routinely observed three times daily, during two days after surgery. On the other days, these vital signs were routinely observed two times daily.

In period 2, respiratory rate, oxygen saturation, systolic blood pressure, heart rate and the eye, motor, verbal (EMV) score were observed three times daily throughout admission.

BP, systolic blood pressure; EMV, eye, motor, verbal; HF, heart frequency; O2, oxygen saturation; P1, period 1; P2, period 2; RR, respiratory rate.

<table>
<thead>
<tr>
<th>Table 5 Calculation formulas RRS costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implementation and maintenance</strong></td>
</tr>
<tr>
<td>Implementation costs = 9896/30298 = €0.33</td>
</tr>
<tr>
<td>Training costs = 27291/30298 = €0.90</td>
</tr>
<tr>
<td><strong>Nursing time spent on extended observation of vital signs</strong></td>
</tr>
<tr>
<td>Nursing time per admission [ \times \text{costs nurse hour} = 0.91 \text{hours} \times 30.5 = €2.20 ]</td>
</tr>
<tr>
<td>Mean LOS [ \times \text{ LOS costs } = 12.6 \times €12.6 = €159.92 ]</td>
</tr>
<tr>
<td><strong>MET consults</strong></td>
</tr>
<tr>
<td>MET consults = 134/30298 = €0.57</td>
</tr>
<tr>
<td><strong>Differences unplanned ICU costs P2 compared to P1</strong></td>
</tr>
<tr>
<td>Unplanned ICU days P2 - Unplanned ICU days P1 [ \times \text{Extra costs ICU day} = 794/30298 = 194/16186 = €22.87 ]</td>
</tr>
<tr>
<td><strong>Mean daily hospital costs P1</strong></td>
</tr>
<tr>
<td>(Costs ward day × Patient days on ward P1 + (Costs ICU day × Unplanned ICU days P1)) / Patient days P1 = (575 × 15992) + (2183 × 194) / 16186 = €594</td>
</tr>
<tr>
<td><strong>Scenario MET consults</strong></td>
</tr>
<tr>
<td>Scenario MET consults = 178/30298 = €0.76</td>
</tr>
<tr>
<td><strong>Scenario differences unplanned ICU costs, scenario compared to P1</strong></td>
</tr>
<tr>
<td>Scenario unplanned ICU days P2 - Scenario unplanned ICU days P1 [ \times \text{Extra costs ICU day} = 476/30298 = 194/16186 = €6.99 ]</td>
</tr>
</tbody>
</table>

*Training costs were only made for the ward personnel of the surgical ward and this initial training was only given during the introduction of the RRS. ICU, intensive care unit; MET, medical emergency team; P1, period 1; P2, period 2; RRS, rapid response system.
and one-fifth extra ICU admissions. Mean RRS costs per patient-day were reduced with €16.69 (62%) to €10.18: MET costs increased with €0.19 to €0.76 and costs for extra unplanned ICU days decreased with €16.90 to €5.99. Details are shown in Table 6.

### Discussion

We estimated the mean costs of the RRS per patient-day and explored the costs of referring patients to the ICU with a mean APACHE II score of 14. Mean RRS costs were €26.87 per patient-day. The major part of the costs, namely 85%, was caused by the increased number of unplanned ICU days after RRS implementation. The scenario analysis showed that lowering the mean APACHE II scores of unplanned ICU admissions to 14 considerably reduced the mean RRS costs per patient-day with 62%, even though one-third extra MET consults and one-fifth extra ICU admissions were added. To our knowledge, this is the first study attempting to estimate the effects of an RRS on hospital costs.

Since most of the RRS costs are attributable to unplanned ICU days, which increased notably after RRS implementation, it is worthwhile to explore the reasons for this phenomenon to see if those costs can be reduced without increasing mortality. Studies show an association between MET consult delays and increased unplanned ICU admissions [17,18] or an increase in ICU LOS [16]. When considering that differences between an ICU day and a ward day are €1608, which is equal to the costs of 12 MET consults, it may be cost reducing to consult the MET earlier and more frequent in order to avoid, or to timely refer patients to the ICU. In addition, co-management of the MET in less severely ill patients on the ward may be considered, even though this would need several MET consults for one patient. Further research is needed to measure the empirical effects on the mean costs per patient-day of these options. Our cost calculation model may be useful to get insight in these costs.

Several aspects of our study need to be discussed. We performed an economic evaluation of the RRS based on cost-effectiveness, however the outcomes were not informative due to wide confidence intervals [5]. Furthermore, a cost-utility analysis was not possible since we found no effect of an RRS on quality of life [19]. However, we feel that a cost analysis of the RRS will be helpful to decide on next steps to improve the RRS and to monitor its effects on costs. The intermediate outcome ‘differences in the number of unplanned ICU days’ is informative as it allows us to assess in relatively short time periods whether this intermediate outcome is changing.

In addition, one could argue that ‘nursing time for extended observations’ and ‘extra time from ICU personnel to perform MET consults’ should not be calculated as costs because the professionals are present and paid for anyway. However, when ward nurses and the MET team are executing RRS tasks, they cannot perform other tasks. Therefore, we consider calculation of the extra time into costs as justifiable.

In our cost analysis, we did not take into account the influence of the MET interventions on costs. To do this, we should also have calculated the intervention costs of the ward doctors and medical specialists before and after RRS implementation. In our present design, this was not considered feasible.

We are aware that our outcomes on the main RRS costs per patient-day are difficult to generalize to other (international) settings. However, we believe that our model of cost calculation including ‘differences in unplanned ICU days’ is also useful in other settings to obtain insight in the RRS costs.

Furthermore, our ‘APACHE II 14’ scenario analysis was built on several assumptions. However, the calculated mean unplanned ICU LOS was based upon empirical data. In our view, we made realistic assumptions for the costs of extra MET consults and extra unplanned ICU admissions. In addition, we did not correct for the possible reduction of costs for avoiding unplanned ICU admissions and unexpected death as an effect of timely MET consults and unplanned ICU referrals of less severely ill patients. Therefore, we consider our scenario analyses as far from optimistic. On the contrary, we are aware of the number of assumptions made, and consequently, we formulated our conclusion in a careful way.

### Conclusion

Mean RRS costs per patient-day for implementation and maintenance, training, nursing time for extended observation of vital signs and MET consults were relatively low; costs for the increased number of unplanned ICU days were relatively high. The ‘APACHE II 14’ scenario confirmed the hypothesis that costs for the number of unplanned ICU days can be reduced if less severely ill patients are referred to the ICU, even though considerably more MET consults and unplanned ICU admissions would be expected. Based upon these findings, our hospital stimulates earlier referral to the ICU, although further implementation strategies are needed to achieve these aims.
References


