Chapter 7

Effects of standardized patient and equipment hand offs in interhospital critical care transport after Failure Mode and Effect Analysis

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ABSTRACT

Background
Regionalization and concentration of critical care increases the need for interhospital transport. Despite the recognized safety issues of in-hospital patient and equipment handoffs, studies on a systematic, prospective analysis of those handoffs in interhospital critical care transports are lacking.

Rationale
The hypothesis of the present study was that safety checklist items based on Hospital Failure Mode Effect Analysis (HFMEA) with questionnaire guided implementation results in improved patient and equipment hand offs in interhospital critical care transport.

Methods
HFMEA was executed by a team of experts of the Mobile Intensive Care Unit, Academic Medical Center in Amsterdam. Risk Priority Numbers (RPN) using the 10-points scales were calculated. A pre-intervention questionnaire among critical care transport nurses and physicians was used to evaluate safety issues perceptions. Protocol adherence was observed before and after the introduction of a redesigned transport form including new patient and equipment hand off checklist items based on RPN’s. A pre-intervention workshop to refine the redesigned form was part of the implementation phase. An observed improvement of protocol adherence > 5% was considered clinically significant.

Results
HFMEA identified 19 hand off items, six with RPN’s > 300. Seventeen out of 29 critical care transport nurses (59%) and 17 out of 17 intensivists (100%) completed the questionnaire. The verbal handover of the sending ICU was evaluated as incomplete by 12 respondents out of 34 (35%), in the receiving ICU by 3 out of 34 (9%). Twenty nine out of 34 respondents (85%) agreed on checklists would improve quality of critical care transports and 30 (88%) agreed on checklists making transports more structured. Twenty five interhospital critical transports could be observed before and after the intervention (n=50 in total).

Ten out of nineteen items (53%) demonstrated an improvement in hand offs after the intervention whereas three items already showed the maximal positive scores before intervention. Five out of six hand off items with RPN > 300 improved after the intervention.

Conclusions
The combination of HFMEA as a prospective risk analysis tool generating essential checklist items, a questionnaire guided implementation and a workflow supporting transport form results in improved patient and equipment hand offs in interhospital critical care transport.
INTRODUCTION

Transport of critically ill patients is increasing most likely due to regionalization of intensive care in referral centers both in the US & Europe. Regionalization is supported by the association between volume and improved outcome in specialties such as critical care. Interhospital critical care transport bears risks of clinical and technical events which should be outweighed against the individual benefit. Critically ill patients depend on invasive mechanical ventilation and vasopressive or inotropic medication which should be continued during transport. The risks associated with interhospital transports have been studied extensively and despite optimal escorting professionals and dedicated equipment, the majority of events seems to be preventable. Incidence rates of critical events during transport varies from 3 to 75% due to different definitions. Incidents due to deterioration of the clinical condition of a critical ill patient during transport are anticipated and weighted against its benefits. However, incidents due to equipment failure or incomplete patient hand off are considered preventable.

Patient hand offs have been recognized to induce loss of information with substantial risk of patient harm. Numerous interventions to improve patient hand offs have been studied. Studies on safety tools (i.e. checklists) in order to prevent transport incidents focus on overall protocol compliance. However, effectiveness of checklist remains debated, especially if risk analysis and checklist fatigue are overlooked. Prospective risk analyses such as the Healthcare Failure Mode and Effect Analysis (HFMEA) have become an essential part in improving high risks health care environments. Such an analysis identifies key factors or process steps where focus on safety would realize the most effective results.

The hypothesis of the present study was that thoroughly implemented safety checklist items based on HFMEA results in improved patient and equipment hand offs in interhospital critical care transport.

METHODS

Context

This before-after study was executed in the Mobile Intensive Care Unit (MICU) based at the Academic Medical Center, University of Amsterdam, Netherlands. The interhospital transports were executed in a ground critical care ambulance in combination with a MICU-trolley for mechanically ventilated patients with or without circulatory support (fig 1). All transports between Intensive Care Units (ICU) of hospitals nationwide were included. Emergency transports defined as interhospital transport from emergency departments for rescue therapy elsewhere were excluded. The annual number of transports is
approximately 350 and the escorting team comprises a critical care nurse and physician. All critical care transport nurses and physicians were members of the ICU staff in the Academic Medical Center. The staff of the MICU (32 critical care nurses, 13 intensivists) was informed about the study on improvement patient safety with focus on hand off during critical care transports.

Figure 1. The Mobile Intensive Care Unit (MICU, trolley and ambulance) & escorting team, Academic Medical Center, University of Amsterdam. An online videoclip illustrates the process of interhospital MICU transport: http://tinyurl.com/MICU-video

Interventions

HFMEA
The prospective risk analysis team consisted of three intensivists and a critical care nurse, all with at least 5 year experience in critical care transport. The team defined patient and equipment hand offs as the topic of HFMEA which were depicted in a flow chart including all identified patient and equipment hand offs during the entire transport process. The pre-initial step of accepting an interhospital transport request by the sending hospital was ignored in the HFMEA. The HFMEA was executed using the 10-point scales to assign scores and calculate the risk priority number (RPN) as the product of the scores of frequency x severity x safeguard\textsuperscript{21}. The severity scale from ranged from 1 (near miss, no harm) to 10 (catastrophic event, death or serious injury), frequency scale from 1 (failure rate 1:10.000) to 10 (failure rate 1:10), and safeguard scale from 1 (almost certain to detect) to 10 (absolute uncertainty to detect in time for intervention)\textsuperscript{21}.
Questionnaire
At baseline before the checklist intervention the escorting team of a critical care nurse and intensivist were asked to fill out the MICU Patient Safety System (MICU-PASS) questionnaire to evaluate their perceived safety after each transport and their opinion on introducing a checklist to improve this. The questionnaire was developed based on Hospital Survey on Patient Safety Culture and included 4 sections: safety perception of the specific critical care transport, teamwork, handoffs, opinion on checklist and background information (i.e. experience in critical care transports). Both closed and scoring questions were used, the latter with a five-point Likert scale [ranging from strongly disagree to strongly agree].

Checklist items
Based upon RPN’s, checklist items were defined by the FMEA team in order to improve patient and equipment hand offs. The original critical care transport form including registration items (i.e. vital signs, ventilator settings) was redesigned and enriched with checklist items based on calculated RPN’s to avoid multiple forms. After analysis the results of the MICU-PASS questionnaire a one hour team workshop for critical care transport nurses was organized to fine tune the new form including new checklist items and was followed up by email communication to implement the redesigned final transport form.

Study of the intervention
Observations of correct execution of check list items at baseline and after introduction of the redesigned transport form was chosen as surrogate endpoints. Observations were performed by a trained observer and each check list item, covering a critical hand off step in the entire transport process, was scored yes if executed accordingly or no if not. Two observers, medical research students, were trained as member of the FMEA team and during three supervised transports in observing the entire MICU-process and scoring all hand off items, from preparation including trolley check, equipment checks during ambulance ride, hand offs in sending and receiving hospitals until final documentation after disinfection / replenishing the MICU-trolley at home base. The observer was present during the entire transport and not part of the escorting team. At baseline the observers collected and evaluated the questionnaires results before the intervention. Results of the questionnaires were used to adjust the implementation workshop.

Analysis
The RPN’s as results of the HFMEA were analyzed and included as checklist items in the work flow of the redesigned transport form by the FMEA team.

A kappa value was determined to assess agreement between nurses and intensivists’ responses to the MICU-PASS questionnaire to allow for pooled analysis and > 0.7
was defined as acceptable. Baseline characteristics of the transported patients and the scored observations at base line and after intervention were summarized using descriptive statistics. A positive observation was “yes” scored after correct execution of a check list item. All yes/no observations before and after the intervention were analysed and percentage difference (number of positive observations after intervention minus number before intervention / number before intervention x 100) > 5% was considered clinically significant.

Continuous variables were expressed as median with their 25th and 75th percentiles, whereas categorical variables were expressed as number and their percentage differences (number after minus number before / number before). Reporting was according to SQUIRE (Standards for Quality Improvement Reporting Excellence) 25

Ethical considerations
The local Medical Ethics Committee waived the need for informed consent according to Dutch Act on Research Involving Human Subjects. The observations of incomplete hand offs were not discussed with the transport team nor the teams in the sending or receiving hospital.

RESULTS

HFMEA
The HFMEA proces map of all patients and equipment hand offs is depicted in figure 2. Fourteen hand off items could be identified, RPN’s were calculated and summarized in table 1. Six items were identified with RPN’s above 300. Five of those were equipment hand offs before departure of the base station and after transport and one was the patient information hand off concerning the intravascular lines.
Effects of standardized patient and equipment hand offs in interhospital critical care transport

**Figure 2.** HFMEA process of hand off steps in interhospital critical care transport

**Questionnaire**

Seventeen out of 29 critical care transport nurses (59%) and 17 out of 17 intensivists (100%) completed the questionnaire after their interhospital transport, resulting in 34 questionnaires. With a kappa of .81 the agreement between nurses and intensivists was considered acceptable to report overall results. No critical incidents were reported in 34 questionnaires. Twenty two out of 34 respondents (65%) have executed > 50 critical care transports, 8 respondents (24%) < 25 transports. Nineteen of 34 respondents (56%) agreed and 8 respondents (24%) totally agreed with the transport being optimal, 4 respondents (12%) disagreed. The verbal handover of the sending ICU was evaluated as incomplete by 12 respondents out of 34 (35%), in the receiving ICU by 3 out of 34 (9%). Cooperation with sending and receiving ICU was evaluated as optimal by 25 (74%) and 26 out of 34 respondents (77%) respectively. Twenty nine out of 34 respondents (85%) agreed or totally agreed that checklists would improve quality of critical care transports and 30 (88%) agreed or totally agreed on checklists making critical care transports more structured. After analysis the questionnaires results did not induced adjustments in the implementation workshop.

**Checklist items**

Fourteen hand off items identified by FMEA were included in the redesigned transport form (electronic supplementary file). Five hand off items were executed twice, both in the sending and receiving hospital (from the sending ICU to transport team & from transport team to receiving ICU) resulting in a total of nineteen hand off items per transport.
Before / after intervention

Twenty five interhospital critical transports could be observed before and after implementation of the redesigned transport (n=50 in total). Observation time took approximately 175 h (mean transport time of 3.5 h including preparation, replenishment and documentation).

The median [25th–75th] age of the transported patients was 63.5 years [50.5-72.0]. Reasons for admission were medical (n=31), surgical (n=13) or neurological (n=6). The indications of transport were expertise in referral center (n=33), return to primary hospital (n=11) or lack of ICU-beds (n=6). The median length of transport distance was 30.0 km [16.0-50.5] and the median transport time 70.0 min [60.0-90.0].
The scored positive observations of hand off items (n=19) are summarized in figure 3. Ten out of nineteen items (53%) demonstrated an improvement in hand offs after the intervention whereas three items already showed the maximal positive scores before intervention. Five out of six hand off items with RPN > 300 demonstrated improvement after intervention and one item ("IC-trolley disinfected after transport", RPN 320) showed positive score in 25 transports before the intervention. One out of nineteen items ("ventilator settings complete, sending ICU to team") demonstrated a deterioration of -20% in positive observations.

Figure 3. Observations were made during n=25 transports before and during n=25 transports after check list implementation. A positive observation was “yes” scored after correct execution of a check list item, depicted on Y-axis. * > +/- 5% = clinically significant

** RPN = Risk Priority Number (product of the scores of frequency x severity x safeguard). The severity scale from ranged from 1 (near miss, no harm) to 10 (catastrophic event, death or serious injury), frequency scale from 1 (failure rate 1:10.000) to 10 (failure rate 1:10), and safeguard scale from 1 (almost certain to detect) to 10 (absolute uncertainty to detect in time for intervention).

DISCUSSION

The present study demonstrates four major findings: i) HFMEA is supportive in clarifying and quantifying critical hand offs of interhospital critical care transport, ii) incorrect equip-
ment hand offs might endanger patient safety significantly in respect to patient hand offs, iii) a questionnaire on quality improvement measures is helpful in the pre-implementation phase of introducing another checklist in the critical care environment and iii) essential checklist items within a designed form supporting workflow results in improved protocol adherence.

The demand for interhospital critical care transports is increasing due to regionalization in healthcare driven by expected or established improved outcome \(^2,^3\). These transports bares essential risks for critical events due to the high complex and changing environment in combination with vulnerable, critically ill patients \(^4,^6\). Studies on reducing these risks focused on specialized retrieval teams and equipment like a Mobile Intensive Care Unit in combination with a dedicated ICU-ambulance, as used in the present study \(^1,^5,^9,^{11,22,26}\). But even with the use of dedicated teams and equipment these risks are not eliminated \(^2,^{22,26}\). Although patient hand offs are well recognized high risk process steps, research on how to improve these scientifically seems to be limited to hospitals. In a Dutch multicenter study among low risks surgical patients the introduction of a system of checklists decreased mortality from 1.5% to 0.8% \(^13\). These results initiate checklists implementation in many departments with conflicting results on its effectiveness \(^18,^27\). A study on the effect of a checklist on hand offs from operating room to ICU demonstrated a significant increased attention on critical items in hand offs \(^14\). Improving critical care transports with checklist focused mainly on intrahospital transports. Checklist items are integrated with vital signs & ventilator settings documentation to fit the flow of work as was done in the present study \(^15,16,24\). A study by Brunsveld e.a. described a method how to develop such a transport checklist \(^16\). A prominent difference with the present study is their absence of the double patient hand offs (sending hospital to team and team to receiving hospital) for their ICU-nurses and physicians were also escorting the intrahospital transport.

Development of check lists items in literature lack a systemic approach of a standardized prospective risk analysis. Their methods rely on review of published intrahospital checklists in combination with a modified retrospective analysis of documented incidents. A clear disadvantage of such a retrospective approach is observation time which could have been too limited to encounter a catastrophic but preventable incident. The use of HFMEA is growing slowly including its application in acute care departments \(^19,^20,^27\). Although time consuming and requiring in-depth multidisciplinary expertise of the process of interest, the classical RPN calculation within HFMEA has demonstrated to identify critical risks in hand offs more accurately compared to more simplified method \(^21\).

Another prominent feature of interhospital transport is the high RPN’s in equipment handoffs. It is obvious that dependency on critical care equipment during an ambulance ride is significant higher compared to intrahospital transport. Critical events could then be solved with more easily with timely supplied backup equipment.
Our study shows that a prospective risk analysis as HFMEA could serve as a systematic and essential first step to develop check lists items, demonstrated in interhospital critical care transport. This analysis should be followed by a thorough implementation process of checklist items incorporated in a workflow driven, preferably one-sided single sheet transport form. And finally, its proper use should be evaluated demonstrating improved protocol adherence. Another aspect of checklists is not merely adherence to certain protocol items by simple not forgetting things. The overall team focus on the process itself might be a crucial factor to enhance patient safety. Despite the growth in checklists in the critical care environment our results demonstrate that a multidisciplinary team approach to hand offs might overcome the problem of checklist fatigue.

Nevertheless, our study suffers from several limitations. Firstly, executing all checklist items in the form as the outcome of the intervention in our study is a surrogate endpoint. Decrease in critical events during transport or outcome after transport might reflect the true effects of checklist and protocols. However, due to low incidence of near fatal incidence this seems unfeasible in practice. To overcome this issue in safety management is to combine prospective with retrospective risk analyses.

Secondly, the Hawthorne effect of the intervention, either the new checklists itself including its implementation focus or the observer during transports might have influenced the results. The impracticability of studying protocol adherence in interhospital transport without direct observation of recordings is clear. Effort should be made to guarantee that positive results of quality improvements will become part of intrinsic standard operational procedures. Thirdly, no time-interrupted measurements were performed to demonstrate such a sustainable effect on protocol adherence. The time consuming nature of observations combined with unpredictable time frames of critical care transports prohibits simple secondary or even tertiary evaluations of the intervention. Timely quality checks as part of a broader quality management system should solve this issue of sustainable improvements in interhospital transport besides patient and equipment hand offs.

Checklists are just one of many quality and safety improvements with its recognized short comings including checklist fatigue and perceived loss of professionalism. After evaluating RPN’s our FMEA-team thoroughly analysed possible new technical innovations to improve patient or equipment hand offs but concluded that technical options have run out. Multiple technical updates of the MICU-trolley already were implemented in the past. The use of sealed compartments, for example, containing disposable material and medication, improved quality and simultaneously reduced time of the routine equipment check by the team before and after transport. Additionally, part of standard operational procedure scheduled became a weekly, thorough cleaning and check of the entire trolley including a visible date stamp of this check to the trolley for double check by the next user. Consequently, equipment check by the team before departure could focus on hand
offs with the highest RPN, i.e. equipment compartments sealed and electric equipment fully charged and operational.

In conclusion, the combination of HFMEA as a prospective risk analysis tool generating essential checklist items and a workflow supporting transport form results in improved hand offs in interhospital critical care transport.

In transport, HFMEA revealed that special focus should be put on equipment besides patient hand offs. The effects of these improved hand offs should be monitored regularly by retrospective risk analyses. Future research should focus on integrating HFMEA in critical care risk management.

AUTHORS CONTRIBUTIONS:

All authors had substantial contributions to the conception, design of the work, the acquisition, analysis, interpretation of data for the work, drafting the work and revising it critically for important intellectual content. They all had final approval of the version to be published, agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conception and design: EJvL, BO, SM, SvdS, RdH, JB, NJ, MV, DD; analysis and interpretation: EJvL, AH, BO, AH, DD; drafting the manuscript for important intellectual content: EJvL, AH, NJ, DD.
REFERENCES


SUPPLEMENTARY FILE:

1. MICU PASS Questionnaire En version
2. Critical care transport form Mobile ICU, AMC Amsterdam [including new checklist items] copyright 2016 MICU

**MICU- PATient Safety System (PASS) Questionnaire**

<table>
<thead>
<tr>
<th>Date of transport:</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Quality of MICU-transport</td>
<td></td>
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</tr>
<tr>
<td>1. a. The quality of my last MICU-transport was optimal.</td>
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<td></td>
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<tr>
<td>1. b. If answered 1, 2 of 3, what might have been the reason?</td>
<td></td>
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<tr>
<td>2. Was there any critical incident during transport?</td>
<td>Yes / No</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>B. Teamwork and patient-info hand off:</td>
<td>Strongly disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td>1. Teamwork with <strong>sending</strong> hospital crew was optimal.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Verbal hand off by <strong>sending</strong> hospital crew was complete.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Written/digital hand off by <strong>sending</strong> hospital crew was complete.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4. Teamwork with <strong>receiving</strong> hospital crew was optimal.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5. Ik beoordeel de <strong>mondelinge</strong> overdracht in het <strong>ontvangst ziekenhuis</strong> als compleet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Checklist</td>
<td>Strongly disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly agree</td>
</tr>
<tr>
<td>1. Vital clinical information is frequently lost by hand offs from hospital to hospital.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2. Use of checklist items will improve patient and equipment hand offs.</td>
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</tr>
<tr>
<td>3. A checklist will optimize the structure of the critical care transport.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Background</td>
<td>ICU-nurse</td>
<td>intensivist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. What is your ICU position?</td>
<td>ICU-nurse</td>
<td>intensivist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Number of MICU-transports you escorted?</td>
<td>0-25 transport</td>
<td>25-50</td>
<td>&gt; 50</td>
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<td></td>
</tr>
</tbody>
</table>
### Chapter 7

**Datum gewicht patiënt**

**Diagnose**

- **Patientsticker** (if no sticker)
  - Name
  - Geboortedatum
  - Patiënt-ID

<table>
<thead>
<tr>
<th>Inschrijvend ziekenhuis</th>
<th>Afzending ziekenhuis</th>
<th>Onderzoekersnaam</th>
<th>Artiest/Speciaalisme</th>
<th>Begin dienst</th>
<th>Eind dienst</th>
</tr>
</thead>
</table>

**Check voor vertrek**

- Checklijst apparatuur houdbaar
  - Ja
  - Nee

<table>
<thead>
<tr>
<th>Tijdstip</th>
<th>VC/PC/PS</th>
<th>Bloeddruk</th>
<th>Hartfrequentie</th>
<th>Medic./Bolus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voorafgaand ziekenhuis</td>
<td>Voorafgaand ziekenhuis</td>
<td>Voorafgaand ziekenhuis</td>
<td>Voorafgaand ziekenhuis</td>
<td>Voorafgaand ziekenhuis</td>
</tr>
</tbody>
</table>

**Ventilatie**

<table>
<thead>
<tr>
<th>Tijd</th>
<th>pomp 1</th>
<th>pomp 2</th>
<th>pomp 3</th>
<th>pomp 4</th>
<th>pomp 5</th>
<th>Infusies</th>
<th>Diurese</th>
</tr>
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<tr>
<td>Voorafgaand ziekenhuis</td>
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<td>Voorafgaand ziekenhuis</td>
</tr>
</tbody>
</table>

**Check na terugkomst AMC**

- Infusie klaar voor instel AMC
- ICU arts
- Begin dienst
- Eind dienst

**Remarks**

- Oxygen cilinders
  - Ja
  - Nee

- Infuus 1
- Diurese
- Medic./Bolus

**Ventilatie**

- Tijdstip
- VC/PC/PS
- Bloeddruk
- Hartfrequentie
- Medic./Bolus

**Check voor vertrek**

- Checklijst apparatuur houdbaar
  - Ja
  - Nee

**Remarks**

- Infuus 1
- Diurese
- Medic./Bolus