Additional telemedicine rounds are a successful performance improvement strategy for sepsis management – an observational multicenter study

Dr. Robert Deisz, MD1*, Susanne Rademacher, MSc1*, Dr. Katrin Gilger, MD1, Dr. Rudolf Jegen, MD2, Dr. Barbara Sauerzapfe, MD3, Fitzner, C, PD Dr. Christian Stoppe, MD1, Dr. Carina Benstoem, MSc1, Prof. Dr. Gernot Marx, MD1

*Both authors contributed equally.

1 Department of Intensive Care Medicine, Medical Faculty RWTH Aachen, Germany
2 Department of Anaesthesiology, St. Elisabeth Hospital, Jülich
3 Department of Anaesthesiology, Franziskus Hospital, Aachen, Germany
4 Department of Medical Statistics, Medical Faculty RWTH Aachen, Germany

Original paper

**Corresponding author:**

Carina Benstoem, PhD, MSc
RWTH Aachen University
University Hospital
Pauwelsstr. 30
D- 52074 Aachen
Phone: +49 241 80 38038
Fax: +49 241 80 82182
cbenstoem@ukaachen.de
Abstract

Background

Sepsis is a major healthcare problem affecting millions of patients with high morbidity and mortality rates. Telemedicine, defined as the exchange of medical information via electronic communication, demonstrated to improve outcome of septic patients and to decrease mortality and length of stay on the intensive care unit (ICU).

Objective

So far, it remains unknown if additional telemedicine rounds could be an effective component of performance improvement programs for sepsis, especially for underserved rural areas and hospitals without ready access to critical care physicians. We hypothesized that an additional telemedicine support may increase adherence to sepsis guidelines and improve the detection rates of sepsis and septic shock. Our objective was to evaluate the impact of additional daily telemedicine rounds on the adherence to the sepsis bundles.

Methods

We conducted a retrospective, observational, multicenter study between January 2014 and July 2015 involving one Tele-ICU-Center and three ICUs in Germany. We implemented telemedicine as part of standard of care and collected the data for this study continuously during the course of the study. During daily-performed telemedicine rounds routinely screening for sepsis was conducted and the adherence to the Surviving Sepsis Campaign (SSC) 3-hour and 6-hour sepsis bundles were evaluated.

Results

In total, 1,168 patients are included in this study. 196 patients were positive for severe sepsis and septic shock. We found that additional telemedicine rounds have a statistically significant effect on the adherence to the 3-hour (76.2% compared to
35%, p = 0.0095) and the 6-hour sepsis bundle (95.2% compared to 50%, p = 0.001). The results were driven by an increase of adherence to the item “Administration of fluids when hypotension” (100% compared to 80%, p = 0.049) of the 3-hour bundle, and by an increase of adherence to the item “Re-measurement of lactate” (100% compared to 65%, p = 0.003). In addition, we observed a decrease in mortality from 50% to 33.3% (quartile 1 (Q1) to Q6, p = 0.35) in patients with severe sepsis and septic shock, whereas patients demonstrated a comparable degree of severity as assessed by SAPS II and SOFA score. ICU length of stay (LOS) after diagnosis of severe sepsis and septic shock remained unchanged over the observed period. Due to a higher number of patients with sepsis in Q5 (N = 60), we observed higher effects on mortality (decrease from 50% to 23.3%, p = 0.046).

**Conclusions**

Additional telemedicine rounds should be considered as an effective component of performance improvement programs for sepsis management.

**Keywords**

Telemedicine; Tele-ICU; sepsis; sepsis bundle compliance; intensive care; SSC; outcome improvement
Introduction

Sepsis is the most frequent cause of morbidity and mortality in most intensive care units (ICUs) worldwide. The incidence of sepsis is still rising due to an ageing population presenting with severe comorbidities and the growing bacterial drug resistance [1]. In Germany, the number of sepsis cases grew by 5.7% per year over the years from 2007 to 2013. Although mortality is constantly decreasing, it is still high (30-50%) [2]. When applying the new Sepsis-3 definition [3], a recently published observational study by the SepNet Critical Care Trials Group found showed even higher rates for ICU and in-hospital mortality (>50%) in patients with severe sepsis or septic shock [4]. In the treatment of septic patients, early detection of sepsis followed by an early initiation of adequate management is known to significantly improve outcome [5].

The European Society of Intensive Care Medicine (ESICM) and the Society of Critical Care Medicine (SCCM) published SSC Guidelines for the management of severe sepsis and septic shock, aiming to reduce the mortality of sepsis by 25% in 5 years [5,6,7]. An impressive body of evidence indicates that adherence to clinical practice guidelines and compliance with sepsis bundles is associated with reduced ICU length of stay, lower mortality rates and improved patient outcome [8,9]. In addition, the SSC Guideline specifically emphasizes the need for performance improvement programs for sepsis [5]. So far, they recommend an interdisciplinary approach to sepsis management, protocol development and implementation, targeted metrics to be evaluated, continuous data collection, and continuous feedback to allow constant performance improvement. While specifics might vary significantly among different improvement programs, a common goal is to improve compliance with sepsis bundles and clinical practice guidelines [5,6,7]. However, recent studies showed that compliance with sepsis bundles is still low [8,10,11].

Telemedicine, defined as the exchange of medical information via electronic communication, can be used to improve the availability and quality of medical care. In addition, telemedicine in the setting of intensive care medicine might improve the early detection and appropriate treatment of severe sepsis and septic shock [12]. Telemedicine facilitates direct interaction among intensive care providers over broad distances as a round-the-clock service with physicians who care for critically ill patients (intensivist-to-physician). Telemedicine enables critical decision support by
exchanging clinical data in real time [13]. Recently, a systematic review demonstrated that telemedicine can improve the outcome of critically ill patients and can decrease ICU mortality and length of stay [14]. However, it remains unknown if additional telemedicine rounds could be an effective component of performance improvement programs for sepsis, especially for underserved rural areas and hospitals without ready access to critical care physicians. We hypothesize that an additional telemedicine support may increase adherence to sepsis guidelines and improve the detection rates of severe sepsis and septic shock. Our objective was to evaluate the impact of additional daily telemedicine rounds by an audio-video-system on the adherence to the 3-hour and 6-hour sepsis bundles on three ICUs in Germany.

**Methods**

**Study design and oversight**

We performed an 18-month retrospective, interventional, multicenter study on three ICUs in three hospitals located in North Rhine Westphalia (Germany). Study duration was between January 2014 and June 2015. The study was reviewed and approved by the local institutional ethics board of the University Hospital RWTH Aachen (262/13). We implemented telemedicine as part of standard of care and collected the data for this study continuously.

**Characteristics of Intensive Care Units**

One ICU (A), focusing on neurosurgery and general surgery, was located at a University Hospital staffed by an intensivist around the clock. Two interdisciplinary ICUs (B and C) were located in community hospitals. ICU B was staffed by a general anaesthesiologist and an internal specialist on weekdays. After regular day shifts, during the night and on weekends, on-call personnel or anaesthesia house-staff was responsible for the treatment of ICU patients. ICU C was staffed by physicians of the department of internal medicine and by anaesthesiologists during regular day shifts, during the night and on weekends an anaesthesiologist was on-call.
Tele-ICU-Center and telemedicine infrastructure

The Telemedicine Center at the University Hospital RWTH Aachen was the leading center for this study. As a preparatory measure, both the tele-ICU-system and the electronic health record (EHR, named FallAkte, Soarian Integrated Care, Siemens, Munich, Germany) were customized for the use on the ICUs and the Tele-ICU. All participating personnel received standardized information including the SSC Guidelines and relevant literature [3,4,5]. Prior to the beginning of the study, a permanently installed tele-ICU-system was implemented at the Telemedicine Center at the University Hospital RWTH Aachen as well as mobile tele-ICU-systems at the participating ICUs (Figure 1). A secure encrypted site-to-site Virtual Private Network (VPN) connection was established. The telemedicine center and the participating ICUs were equipped with identical audiovisual transmission equipment (Cisco Systems, Inc., San José, California, USA). In addition, the Telemedicine Center received a workstation, multiple monitors and a video system (Cisco). The participating ICUs were equipped with a mobile audio-video-system that can be taken to the patient's room during rounds. The videoconferencing allowed two or more units to communicate simultaneously by a two-way high-resolution video and audio transmission. The video system included an option for close-up zoom that allowed examining both the patient and the bedside equipment in close detail. To enable exchange of medical data, the secure data protection platform FallAkte was established. Accordingly the system integrated a “store and forward” technique for the structured data combined with real time audio-visual telemedicine rounds where vital signs were checked. After check for missing data all patient data were anonymised and exported to the University Hospitals research database. Figure 1 outlines the structure of the Telemedicine Center and the participating ICUs.
The Telemedicine Center was staffed with an intensive care physician from 7.30 am to 4 pm on weekdays and from 9 am to 5.30 pm on weekends. Telemedicine rounds were performed on a daily basis. If required, additional rounds were offered after core hours and at night by the intensive care consultant on duty, ensuring an accessibility of telemedical consultations around the clock.

Medical documentation in two ICUs was entirely paper-based before the study started. To allow standardized documentation, project specific templates were designed (Adobe Life Cycle) and filled in by physicians on both sides (telemedicine center and ICUs) during daily rounds. The templates covered basic demographic data of patients and summaries of diagnoses as well as performed procedures and therapies. Furthermore the severity of disease and functional limitations of the patient were assessed by applying the Simplified Acute Physiology Score II (SAPS II) and the Sepsis-related Organ Failure Assessment (SOFA) \[13\] score. A systematic checklist for daily infection assessment was applied. During rounds, both case
presentation and assessment by the local physician and the intensivist in the tele-ICU were performed; diagnostic or therapeutic interventions were discussed. Direct feedback regarding sepsis management was given. Typically, conscious patients and/or their relatives were present during telemedicine rounds.

All telemedicine rounds were observed and documented by a research assistant. The following items were documented: recommendations for diagnosis and therapy of sepsis, adjustments of sepsis management, details regarding antibiotic therapy (continued, evaluated, changed, terminated), scoring of SAPS II and SOFA, duration of ICU LOS and ICU LOS after sepsis diagnosis.

Definitions

Applied definitions of sepsis, severe sepsis or septic shock are outlined in Table 1.

Table 1 – Definitions of sepsis, severe sepsis or septic shock [7,15]

| Sepsis | Presence (probable or documented) of infection with systemic manifestation:
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td><strong>General variables:</strong></td>
</tr>
<tr>
<td></td>
<td>Fever &gt;38.3°C, hypothermia &lt; 36°C, heart rate &gt; 90 bpm or more than two SD above the normal value for age, tachypnea, altered mental status, significant oedema or positive fluid balance &gt;20 ml/kg over 24 hours, hyperglycaemia with a plasma glucose &gt; 140 mg/dl or 7.7mmol/L in the absence of diabetes mellitus</td>
</tr>
<tr>
<td></td>
<td><strong>Inflammatory variables:</strong></td>
</tr>
<tr>
<td></td>
<td>Leukocytosis (WBC count &gt; 12,000 µl⁻¹), leukopenia (WBC count &lt; 4,000 µl⁻¹), normal WBC with greater than 10% immature forms, plasma C-reactive protein more than two SD above the normal value, plasma procalcitonin more than two SD above the normal value</td>
</tr>
<tr>
<td></td>
<td><strong>Hemodynamic variables:</strong></td>
</tr>
<tr>
<td></td>
<td>Arterial hypotension (SBP &lt;90 mmHg, mean BP &lt;65 mmHg, or reduction in SBP &gt;40 mmHg from baseline) persisting for at least 1 hour, despite adequate fluid resuscitation</td>
</tr>
<tr>
<td></td>
<td><strong>Organ dysfunction variables:</strong></td>
</tr>
</tbody>
</table>

8
| Severe sepsis | Sepsis plus sepsis-induced organ dysfunction or tissue hypoperfusion:
 | Altered mental state
 | Arterial hypoxemia (PaO\textsubscript{2}/FiO\textsubscript{2} < 300)
 | Acute kidney injury (urine output < 0.5 ml/kg/h for at least 2h or creatinine increase > 0.5 mg/dL)
 | Thrombocytopenia (platelet count < 100,000/µL)
 | Coagulopathy (INR > 1.5 or aPTT > 60 s)
 | Hyperbilirubinemia (total plasma bilirubin > 2 mg/dl)
 | Hyperlactatemia (> 1 mmol/L)
 | Sepsis-induced hypotension
 | Decreased capillary refill or mottling

| Septic shock | Sepsis-induced hypotension (SBP < 90 mmHg or MAP < 70 mmHg or SBP decrease > 40 mmHg) persisting despite adequate fluid resuscitation

**Abbreviations**
- C: Celsius
- bpm: beats per minute
- SD: standard deviation
- ml: milliliter
- kg: kilogram
- mg: milligram
- dl: deciliter
- mmol: millimol
- L: liter
- WBC: white blood cell
- µl: microliter
- SBP: systolic blood pressure
- mmHg: millimeter of mercury
- MAP: mean arterial pressure
- aPTT: activated partial thromboplastin time
- SBP: systemic blood pressure
- INR: international normalized ratio

**Evaluation of adherence to 3-hour and 6-hour sepsis bundles in septic patients**

We continuously extracted data during the course of this project to evaluate whether sepsis management fulfilled the requirements of the 3-hour and 6-hour sepsis bundle during follow-up in septic patients. Time ‘0’ was defined as the time when the attending physician made the diagnosis of sepsis. Items of the 3-hour and 6-hour bundles for patients with severe sepsis and septic shock were adapted from the SSC.
standard sepsis resuscitation guideline. The 3-hour bundle includes the following recommendations: measurement of lactate levels, blood cultures obtained prior to administration of antibiotics, administration of broad spectrum antibiotics and administration of 30ml/kg crystalloid fluid for hypertension or when lactate level was ≥4mmol/L. The 6-hour bundle consists of the following core items: application of vasopressors when hypotension was persistent (mean arterial pressure (MAP) <65mmHg) despite initial fluid resuscitation, assessment of central venous pressure (CVP) and central venous oxygen saturation (ScvO2) when hypotension persisted despite initial fluid administration or when initial lactate levels were ≥4 mmol/L, and re-measurement of lactate levels when initially elevated. The second bundle was also reported for patients remaining with persistent hypotension and/or high lactate level within the six-hour period.

For the evaluation of the adherence to the 3-hour and 6-hour sepsis bundles, we classified septic patients with a ‘yes’ score if all core items of the respective bundle had been executed within 3-hours resp. 6-hours after time ‘0’. Otherwise a ‘no’ score was operated.

**Statistical analysis**

Categorical data are presented as frequency and percentage. Frequencies of categorical data were compared between groups by exact fisher test. Continuous variables are expressed as mean values ± standard deviation (SD). Differences of continuous data between groups were analysed by t-test assuming unequal variances. Statistical tests were performed two-tailed and p-values less than 0.05 were considered as significant test results. SAS software version 9.4 (SAS Institute Inc., Cary, NC, USA) and GraphPad Prism software version 6.0 (GraphPad Software, La Jolla, CA, USA) was used for statistical analyses.

**Results**

During the project duration of 18 months, 1,168 patients were included in the study and received in total 4,569 telemedicine rounds in addition to their daily rounds at the local ICUs. Physicians at the three ICUs performed in total 4,373 infections and
sepsis screenings. Overall, we observed a decrease in mortality from 50 % in quarter 1 (Q1, January 1, 2014 until March 31, 2014) to 33.3 % in Q6 (April 1, 2015 until June 30, 2015, p = 0.3499) in patients with severe sepsis and septic shock, whereas patients demonstrated a comparable degree of severity, as assessed by SAPS II and SOFA score. Due to a higher number of patients with sepsis in Q5 (N = 60), we observed even higher and statistically significant effects (decrease of mortality from 50 % to 23.3 %, p= 0.046). ICU LOS after diagnosis of severe sepsis and septic shock remained unchanged over the observed period. We report the study characteristics, the number of scorings, the number of therapeutic recommendations made and the overall number of sepsis detections per quarter in Table 2. The mean age of included patients was 64.91 (± 17.09), 55% of the patients were male. In total, 196 patients were positive for severe sepsis (N = 95) or septic shock (N = 101) during the study period and were included in our analysis. Table 3 summarizes patient characteristics and provides details on ICU LOS and ICU LOS after diagnosis of sepsis for Q1, Q5 and Q6.

Table 2 – Study characteristics, number of scorings, number of therapeutic recommendations and number of sepsis detections

<table>
<thead>
<tr>
<th>Study characteristics</th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Total n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,168</td>
</tr>
<tr>
<td>Mean age of patients (years ± SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64.91 (± 17.09)</td>
</tr>
<tr>
<td>Male patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>Total number of rounds</td>
<td>541</td>
<td>596</td>
<td>953</td>
<td>812</td>
<td>1074</td>
<td>593</td>
<td>4,569</td>
</tr>
<tr>
<td>Total number of infections- and sepsis-</td>
<td>424</td>
<td>591</td>
<td>990</td>
<td>775</td>
<td>1030</td>
<td>563</td>
<td>4,373</td>
</tr>
<tr>
<td>screenings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of Scorings (SAPS II, SOFA)</td>
<td>541</td>
<td>596</td>
<td>953</td>
<td>812</td>
<td>1074</td>
<td>593</td>
<td>4,569</td>
</tr>
<tr>
<td>Total number of diagnostic</td>
<td>90</td>
<td>77</td>
<td>162</td>
<td>108</td>
<td>203</td>
<td>97</td>
<td>737</td>
</tr>
<tr>
<td>recommendations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of</td>
<td>111</td>
<td>82</td>
<td>285</td>
<td>202</td>
<td>363</td>
<td>153</td>
<td>1,196</td>
</tr>
</tbody>
</table>
### Table 3 – Characteristics of patients with severe sepsis and septic shock

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Initiation of telemedicine rounds</th>
<th>After implementation in Q5 (n=60)</th>
<th>After implementation in Q6 (n=21)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients with severe sepsis (%)</td>
<td>10 (50%)</td>
<td>34 (56.7%)*</td>
<td>6 (28.6%)#</td>
<td>.615</td>
</tr>
<tr>
<td>Number of patients with septic shock (%)</td>
<td>10 (50%)</td>
<td>26 (43.3%)*</td>
<td>15 (71.4%)#</td>
<td>.615</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>10 (50%)</td>
<td>14 (23.3%)*</td>
<td>7 (33.3%)#</td>
<td>.046</td>
</tr>
<tr>
<td>LOS ICU (days)</td>
<td>18.2 (± 21.59)</td>
<td>15.65 (± 15.45)*</td>
<td>19.48 (± 21.44)#</td>
<td>.63</td>
</tr>
<tr>
<td>LOS ICU after diagnosis of sepsis (days)</td>
<td>15.65 (± 21.14)</td>
<td>13.22 (± 13.85)#</td>
<td>16.76 (± 20.7)#</td>
<td>.635</td>
</tr>
<tr>
<td>SAPS II</td>
<td>44.35 (± 12.13)</td>
<td>44.16 (± 16.37)*</td>
<td>45.76 (± 14.41)#</td>
<td>.956</td>
</tr>
<tr>
<td>SOFA</td>
<td>7.7 (± 3.08)</td>
<td>7.18 (± 3.92)*</td>
<td>7.52 (± 3.59)#</td>
<td>.546</td>
</tr>
</tbody>
</table>

* Comparison Q1 to Q5, # comparison Q1 to Q6

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Our primary objective was to evaluate the impact of additional daily telemedicine rounds on the adherence to the sepsis bundles to determine if additional telemedicine rounds are an effective performance improvement strategy for sepsis management. We found that additional telemedicine rounds have a statistically
significant effect on the adherence to the 3-hour (35% compared to 76.2%, p = 0.0095) and the 6-hour bundle (50% compared to 95.2%, p = 0.0014). The results were mainly driven by an increase of adherence to the item "Administration of fluids when hypotension" (80% compared to 100%, p = 0.0478) of the 3-hour bundle; and by an increase of adherence to the item "Re-measurement of lactate" (65% versus 100%, p = 0.0034). Regarding the impact of telemedicine rounds on adherence to sepsis bundles all results are displayed in detail in Table 4 and Figure 2. In addition, figure 3 displays the change in mortality for patients diagnosed with sepsis in a graph.

Table 4 – Impact of telemedicine rounds on adherence to sepsis bundles

<table>
<thead>
<tr>
<th></th>
<th>Initiation of telemedicine rounds Q1 no. (%)</th>
<th>After implementation Q6 no. (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>20</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Compliance 3-h bundle</td>
<td>7 (35%)</td>
<td>16 (76.2%)</td>
<td>.0095</td>
</tr>
<tr>
<td>Compliance 6-h bundle</td>
<td>10 (50%)</td>
<td>20 (95.2%)</td>
<td>.001</td>
</tr>
</tbody>
</table>

**Components / target values of the 3-h bundle**

<table>
<thead>
<tr>
<th>Component</th>
<th>Before implementation no. (%)</th>
<th>After implementation no. (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum lactate measurement</td>
<td>20 (100%)</td>
<td>21 (100%)</td>
<td>1.000</td>
</tr>
<tr>
<td>Blood cultures before antibiotics</td>
<td>11 (55%)</td>
<td>16 (76.2%)</td>
<td>.197</td>
</tr>
<tr>
<td>Administration of Antibiotics within the first 3 h</td>
<td>19 (95%)</td>
<td>21 (100%)</td>
<td>.488</td>
</tr>
<tr>
<td>Administration of fluids when hypotension</td>
<td>16 (80%)</td>
<td>21 (100%)</td>
<td>.049</td>
</tr>
<tr>
<td>Administration of vasopressors when indicated</td>
<td>18 (90%)</td>
<td>20 (95.2%)</td>
<td>.606</td>
</tr>
<tr>
<td>CVP &gt;8mmHg</td>
<td>16 (80%)</td>
<td>19 (90.5%)</td>
<td>.342</td>
</tr>
<tr>
<td>ScvO2 &gt;70%</td>
<td>5 (25%)</td>
<td>9 (42.9%)</td>
<td>.326</td>
</tr>
</tbody>
</table>

**Components / target values of the 6-h bundle**

<table>
<thead>
<tr>
<th>Component</th>
<th>Before implementation no. (%)</th>
<th>After implementation no. (%)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration of vasopressors when indicated</td>
<td>18 (90%)</td>
<td>20 (95.2%)</td>
<td>.606</td>
</tr>
<tr>
<td>Assessment of CVP when indicated</td>
<td>16 (80%)</td>
<td>19 (90.5%)</td>
<td>.41</td>
</tr>
<tr>
<td>Assessment of ScvO2 when indicated</td>
<td>4 (20%)</td>
<td>9 (42.9%)</td>
<td>.181</td>
</tr>
<tr>
<td>Re-measurement of lactate</td>
<td>13 (65%)</td>
<td>21 (100%)</td>
<td>.003</td>
</tr>
</tbody>
</table>
Figure 2 – Impact of additional telemedicine rounds on adherence of sepsis bundles

Figure 3 – Impact of additional telemedicine rounds on mortality
Discussion

To the best of our knowledge this is the first study to evaluate if additional telemedicine rounds should become a backbone of performance improvement strategies for sepsis management, especially for underserved rural areas and hospitals without ready access to critical care physicians. In total, 1,168 patients are included in this study; 196 patients were positive for severe sepsis and septic shock. The number and percentage of severe sepsis and septic shock were in the range of expectations and recent epidemiologic surveys \[16,17,18\]. We were able to demonstrate vigorously that additional telemedicine rounds have a significant effect on the adherence to the 3-hour and the 6-hour sepsis bundle. Additional telemedicine rounds in sepsis management improve adherence to current clinical practice guidelines and improve patient care. The results were driven by an increase of adherence to the item “Administration of fluids when hypotension” of the 3-hour bundle; and by an increase of adherence to the item “Re-measurement of lactate”. In addition, we observed a decrease in mortality in patients with severe sepsis and septic shock, whereas patients demonstrated a comparable degree of severity, as assessed by SAPS II and SOFA score. ICU LOS after diagnosis of severe sepsis and septic shock remained unchanged over the observed period. Due to a higher number of patients with sepsis in Q5 (N = 60), we observed even higher and statistically significant effects.

Additional telemedicine rounds with a standardized daily sepsis screening improved guideline adherence significantly. Near real-time feedback in an intensivist driven tele-ICU-system is an effective performance improvement strategy for rapid implementation of evidence-based practice to achieve improved quality of care. In Germany, the foundation stone to implement Telemedicine was laid when the first guideline on Telemedicine in intensive care was published by the Association of the Scientific Medical Societies (Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften, AWMF) and the German Society of Anaesthesiology and Intensive Care Medicine (Deutsche Gesellschaft für Anästhesiologie und Intensivmedizin, DGAI) \[19\]. Previous studies showed that performance improvement programs are associated with increased adherence to resuscitation and management sepsis bundles and with reduced mortality in patients with sepsis, severe sepsis or septic shock \[20\]. Now it is a continuous effort of all
involved stakeholders to implement Telemedicine nationwide as part of daily routine and standard of care. Here, it will continue to be important in the future to constantly measure the influence of telemedicine on quality indicators for intensive care as demonstrated within this study.

In light of recent findings by Faine and colleagues [21], who showed that inter-hospital transfers delay appropriate treatment for patients with severe sepsis and septic shock, the implementation of Telemedicine is also of special importance. Telemedicine can improve on-site quality of care by shared expertise, being a viable alternative to urgent patient-transfers to university centres. Telemedicine co-management, as recently demonstrated by Pannu et al. [22], slightly increased patient transfers to high-level centers. In principal, however, our findings are consistent with the findings reported by two systematic reviews and meta-analyses, and multiple study reports, which also highlight that telemedicine is associated with lower ICU mortality [23, 24, 25,26] and lower ICU LOS [23, 26, 27]. Furthermore, Lilly et al. also emphasize that Telemedicine has the potential to improve adherence to ICU best practices, reduce response times to alarms, and encourage the use of performance data on the ICU [24].

Given the explorative nature of this first study we acknowledge some limitations, which need to be considered during interpretation of present results. First, we only included a small number of participating hospitals, resulting in a small numbers of patients. However, these are first results, which provide crucial data for following large-scale trials. Second, the level of acceptance, an important factor for the success for telemedicine in general and especially on the ICU was not measured systematically within this project, therefore we cannot estimate its possible influence as a confounding factor. However, personal communication during the telemedicine rounds revealed positive feedback and a high level of acceptance by participating physicians, nurses, patients and their relatives. Here, our experience is in line with the findings of Young et al. [27], who reported high levels of staff acceptance of tele-ICU coverage. We acknowledge that in the future this aspect as a possible confounding factor should be subject to rigorously planned, methodologically high-quality studies. Third, the geographical and time-specific design may limit the extrapolation of the results to other medical centers and patients. We believe that an advanced technical setup will further improve the acceptance for example by
reducing the workload for documentation. Automatic data capture for example by export of the international Health Level 7 standard (HL7) into an active tele-ICU-system with automatic calculation of disease severity or automatic sepsis-alerts will probably improve care beyond the results of this project. Last, it is important to reflect on the generalizability of a retrospective data analysis due to the explorative nature of this study. However, in contrast to other tele-ICU publications we continuously documented sepsis onset and sepsis-bundle-compliance throughout our study and not in a retrospective manner. This approach reduced difficulties associated with the retrospective identification of the time of onset of sepsis as “time zero” for the evaluation of sepsis bundle-compliance. This approach might limit the explanatory power concerning effect-size and causality of the tele-ICU-concept, but it offers a relevant patient benefit of positive outcomes for the patient enrolled in such an implementation study.

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Conflicts of Interest

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