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NIV by an interdisciplinary respiratory care team in severe respiratory failure in the emergency department limited to day time hours

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Abstract Non-invasive ventilatory support is frequently used in patients with severe respiratory failure (SRF), but is often limited to intensive care units (ICU). We hypothesized that an instantaneous short course of NIV (up to 2 h), limited to regular working hours as an additional therapy on the emergency department (ED) would be feasible and could improve patients dyspnoea measured by respiratory rate and Borg visual dyspnea scale. NIV was set up by an interdisciplinary respiratory care team. Outside these predefined hours NIV was performed in the ICU. This is an observational cohort study over 1 year in the ED in a non-university hospital. Fifty-one % of medical emergencies arrived during regular working hours (5475 of 10,718 patients). In total, 63 patients were treated with instantaneous NIV. Door to NIV in the ED was 56 (31–97) min, door to ICU outside regular working hours was 84 (57–166) min. Within 1 h of NIV, the respiratory rate decreased from 30/min (25–35) to 19/min (14–24, $p < 0.001$), the Borg dyspnoea scale improved from 7 (5–8) to 2 (0–3, $p < 0.001$). In hypercapnic patients, the blood-pH increased from 7.29 (7.24–7.33) to 7.35 (7.29–7.40) and the pCO_2 dropped from 8.82 (8.13–10.15) to 7.45 (6.60–8.75) kPa. In patients with SRF of varying origin, instantaneous NIV in the ED during regular working hours was feasible in a non-university hospital setting, and rapidly and significantly alleviated dyspnoea and reduced respiratory rate. This approach proved to be useful as a bridge to the ICU as well as an efficient palliative dyspnoea treatment.

Keywords Non-invasive ventilation · Severe respiratory failure · Emergency department

Introduction

Severe respiratory failure (SRF) is marked by an inadequate gas exchange within the lung, and can be progressive, and fatal. Therefore, the management of SRF remains a challenge on the emergency department (ED) [1, 2]. Adding non-invasive ventilation (NIV) to the standard treatment improves outcomes such as decreased intubation rates and mortality in patients suffering from acute exacerbated COPD (AECOPD), acute cardiac pulmonary edema (ACPE), hypoxic failure in immunocompromised patients, and with hematologic malignancies [1, 3].

Most studies concentrate on either hypercapnic failure (type 2 respiratory failure—mainly AECOPD) [4, 5] or on hypoxemic failure (type 1 respiratory failure—mainly ACPE) [6, 7]. Experience in NIV is important, otherwise high failure rates are noted [8]. In most Swiss centers, NIV in SRF is performed in high dependency units or in the ICU [9]. To the best of our knowledge, there are no data in Switzerland on using NIV in the ED and no known dedicated program for NIV in the ED.

Almost all studies on NIV were performed at university hospitals and there is a paucity of data how and if NIV is performed in smaller hospitals. Since not all patients with SRF are directly transferred to larger hospitals a delay of NIV treatment may exist. The average length of stay (LOS) in the ED in this group is approximately 4 h or longer during times of high patient load [10, 11]. Increased LOS

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in the ED correlates with adverse outcomes [10]. Thus, these patients may benefit from an immediate initiation of NIV in the ED.

We hypothesized that instantaneous NIV as a treatment in the ED would be feasible in a non-university hospital and efficacious in reducing symptoms of SRF [respiratory rate (RR) to below 25/min and dyspnea—Borg visual dyspnea score—to below 5/10] within a short period of time (60–120 min). Furthermore, we assumed that most SRF patients (>50 %) could benefit from this treatment during daytime working hours (50 h/week).

Methods

This study was approved by the regional ethics review board (EKSG 13/118).

Participants

All internal medicine patients admitted to the ED of our hospital (Cantonal Hospital of St. Gallen, Switzerland) from March 1st 2012 until February 28th 2013 regardless of resuscitation status, gender, age or insurance were screened ($n = 10{,}718$).

SRF was defined as either RR > 25/min, [12] SpO_2 < 92 % despite supplemental oxygen of 6 l/min, or hypoventilation (arterial carbon dioxide partial pressure, $paCO_2$ > 7.4 kPa). The indication for NIV was evaluated by an emergency physician, responsible for triage in the ED. NIV in the ED as an additional treatment to standard medical care (typically inhalation of beta-sympathomimetics in eCOPD, diuretics and nitrates in ACPE, antibiotics in lower respiratory infections, as well as opioids and supplemental oxygen) was available on regular workdays from 8 AM to 6 PM (Fig. 1). NIV was initiated by a respiratory therapist (RT) together with a pneumologist, thus composing the respiratory care team (RespiCare). Outside this limited time frame patients received standard care, and—if needed—NIV in the ICU.

Absolute contraindications to NIV were severe abdominal distress (repetitive vomiting, peritonitis) and primary metabolic acidosis, relative contraindications were myocardial infarction, pneumothorax, severe hypotension (systolic blood pressure (SBP) <90 mmHg), confusion or altered mental state with a Glasgow coma scale of <9, overdose of sedatives or analgesics if treatable with antagonists.

Measurements

The co-primary outcomes were timely accessibility and feasibility of NIV and the improvement of dyspnea and RR, defined as a RR < 25/min and a modified Borg visual dyspnea scale <5 (severe dyspnea) within up to 2 h of NIV treatment [12]. Secondary endpoints were changes in pCO_2, pH, mean blood pressure (BP), heart rate (HR), required oxygen supply and arterial oxygen saturation of hemoglobin (SpO_2).

Multidisciplinary respiratory team

The team of RTs, located in the pneumology ward, includes 10 personnel with pass in intermediate care classes, or scheduled to do so. In the pulmonary ward we regularly initiate and optimize NIV. In 2013, they delivered 2300 h of non-invasive ventilation/capita. We opted to use this team in the ED due to their extensive experience and skills. Furthermore, NIV had not been performed routinely in the ED of our hospital before, and the team of ED doctors and nurses had not had any experience with the NIV machines and the masks. Mechanical ventilation for intubated patients in our hospital is typically handled by our anaesthesiologists. Since specific skills and experience are required for successful NIV [8], which are present in RespiCare teams, we sought proof-of-concept to bring these skills into an ED via a "mobile" RespiCare team. Such an approach allows NIV in an ED, which does not have an integrated RespiCare team.

Choice of ventilator

NIV was applied using a battery-powered ventilator (Resmed Stellar™ 100 or 150, ResMed, Basel, Switzerland) equipped with a 2.5-m single-use tubing and a single-use vented mask (ResMed), no heating or humidifying devices were used in the ED. We almost exclusively used a full face mask.

NIV initiation and adaption

Initially a blood gas analysis (either venous or arterial) (Radiometer ABL800 Flex, Thalwil, Switzerland) was drawn and a real-time transcutaneous CO_2 ($ptCO_2$) monitoring (SenTec Digital Monitor SDM, Therwil, Switzerland) was initiated to follow the CO_2 and SpO_2 levels. Oxygen was supplied directly into the single-use mask. NIV was always started using a CPAP mode setting since we assumed most patients would suffer either from ACPE or AECOPD, the latter is sometimes clinically difficult to distinguish from ACPE, and brain natriuretic peptide levels are not always available as a point of care test. The CPAP pressure was chosen depending on the suspected disease. For AECOPD, a pressure between 6 and 8 hPa, and for ACPE, a pressure between 8 and 10 hPa was chosen. If SpO_2 was <92 % and ≥10 l supplemental oxygen was

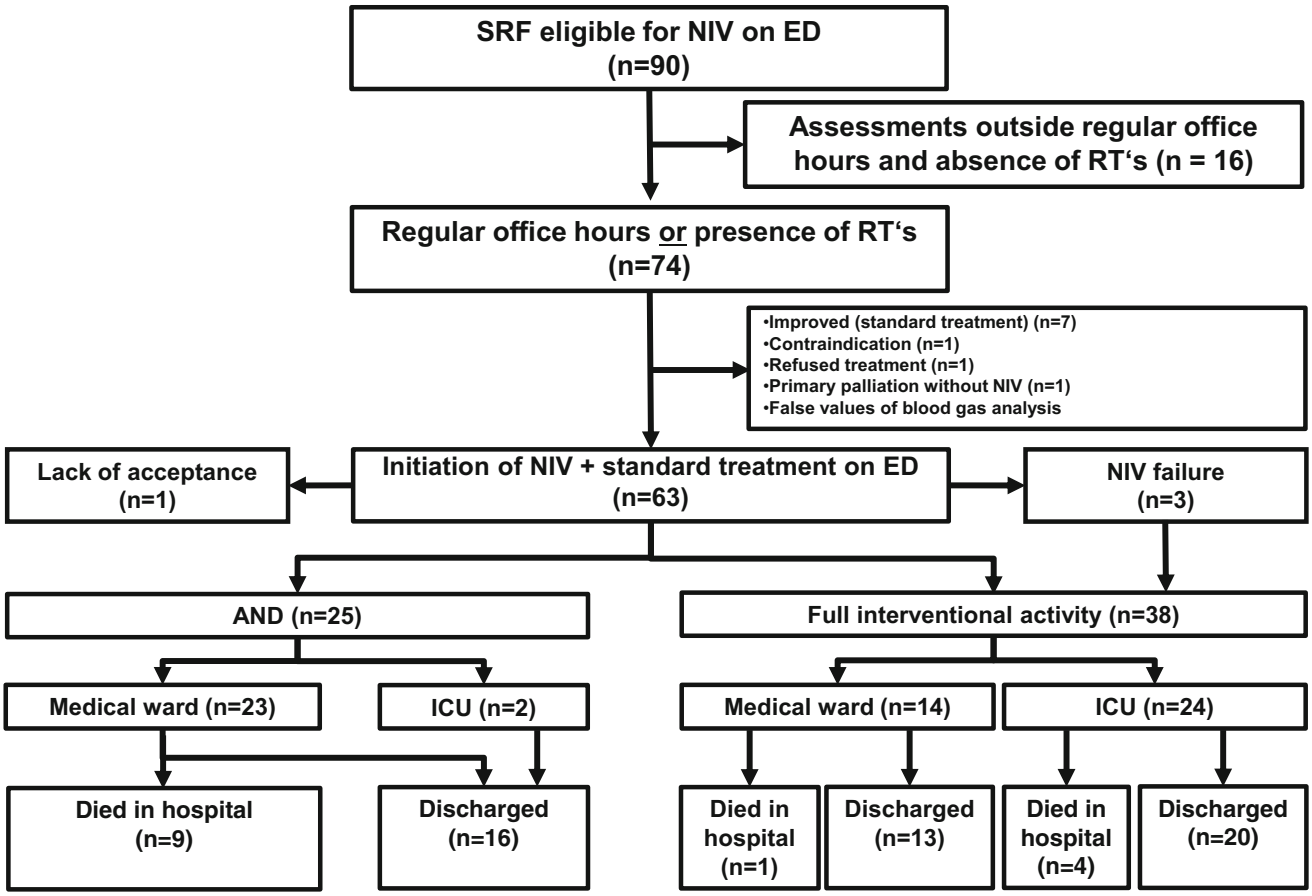


Fig. 1 Study synopsis. *SRF* severe respiratory failure, *NIV* non-invasive ventilatory support, *RTs* respiratory therapists, *ED* emergency department, *AND* allow natural death-order, *ICU* intensive care unit

applied for more than 5 min, patients were reevaluated for invasive ventilation. Settings and modes of ventilation were reevaluated at least every 5 min. During the same period RR, SpO_2, HR, BP, $ptCO_2$ and supplemental oxygen were documented. CPAP was changed to a non-invasive positive pressure ventilation (NPPV) mode if the patient did not improve clinically, or if the $ptCO_2$ did not decrease. The standard settings for the trigger were always in the middle position, except for COPD, where the cycling trigger was set to "sensitive" as standard. Inspiration times were initially set to 0.5–1.5 s, but these were adapted to inspiration times observed during CPAP mode. Expiratory pressure was chosen according to the CPAP pressure—typically between 5 and 12 hPa—pressure support was chosen between 4 and 21 hPa. The initial backup rate was usually set at 10/min. In a few cases, ventilation settings were switched to the built-in adaptive ventilation support (iVAPS®). For iVAPS®, a maximum inspiratory pressure of 25 hPa was defined. Minute ventilation then was adapted according to the minute ventilation achieved during CPAP mode, and whether relevant hypercapnia was present or not. Every 30 min, a BGA was performed until a pCO_2 value below 6.5 kPa was achieved in hypercapnic patients.

Statistical data analysis

Data were collected retrospectively and analyzed using descriptive statistics. Parameter distributions were characterized by box plot representations. Paired Student's *t* test was used to assess the significance of the patient's differences pre- vs. post-NIV therapy. A p value <0.05 was considered statistically significant. All analyses were done using the R statistical software (version 2.15.2).

Results

Patient characteristics

In total, 90 patients presenting with SRF were considered eligible for acute NIV in the ED (Fig. 1). In 16 cases, the arrival time was outside regular working hours, and the RespiCare team was absent. Seven were transferred to the

Table 1 Basic characteristics of the subjects

	n	$paCO_2$ (kPa)	pH	RR	VAS[c] (0–10)	SpO_2 (%)	Oxygen supply (l/min)	MAP[d] (mmHg)	HR[e] (bpm[f])
AECOPD	25	8.1 (6.5–8.9)	7.32 (7.30–7.41)	30 (25–35)	7 (5–8)	91 (84–95)	2 (0–4)	92 (87–104)	111 (96–130)
ACPE[a]	11	5.3 (4.7–6.7)	7.38 (7.23–7.45)	30 (24–38)	7 (7, 8)	93 (87–94)	6 (3–8)	98 (91–118)	107 (91–113)
LRTI[b]	11	7.8 (4.7–10.1)	7.32 (7.25–7.41)	31 (27–40)	7 (6–8)	89 (81–92)	4 (2–12)	91 (77–96)	109 (96–124)
COPD + LRTI[b]	3	8.0 (6.0–9.1)	7.29 (7.28–7.37)	28 (26–31)	7 (6–8)	88 (79–89)	5 (3–6)	94 (93–98)	100 (92–103)
Other	13	8.8 (8.4–10.4)	7.32 (7.20–7.36)	30 (20–35)	6 (0–9)	90 (88–94)	5 (2–10)	90 (58–105)	97 (87–125)

[a] Acute cardiogenic pulmonary edema

[b] Lower respiratory tract infection

[c] Modified Borg dyspnoea visual analogue scale

[d] Mean arterial pressure

[e] Heart rate

[f] Beats per minute

ICU, four underwent NIV, 10 patients were treated with standard care and transferred to the medical ward, and one patient was subsequently treated with NIV in the pulmonary ward due to hypercapnic respiratory failure. Of the remaining 74 patients, 11 were excluded (7 due to rapid improvement with standard care, and 1 each because of the clinical finding of an acute peritonitis, refusal, primary palliation or false-positive blood gas analysis), respectively. Sixty-three patients received instantaneous NIV in addition to current standard care, which was feasible in 62/63 (98 %) SRF patients admitted during operating hours. One patient was unable to tolerate the mask within 1 min after starting therapy (1/63).Twenty-four of 38 patients who had no treatment restrictions were placed in the ICU (Fig. 1), 2 of 23 patients with an allow-natural-death-order (AND) were nevertheless transferred to the ICU. The basic characteristics of the patients are summarized in Table 1. Most patients were suffering from AECOPD ($n = 25$), ACPE ($n = 11$), lower respiratory infection ($n = 11$) and other diseases ($n = 13$, pulmonary embolism, acute worsening of obesity hypoventilation, exacerbation of idiopathic pulmonary fibrosis, fluid lung due to malcompliance with hemodialysis, opiate intoxication, reperfusion lung edema after pleural puncture).

ED arrival and placement characteristics

Fifty-one % of medical emergencies arrived during regular working hours (5475 of 10,718 patients). The length of stay (LOS) in the ED was 197 (135–274) min for all patients, and 128 (76–190) min for those transferred to the ICU. Patients arriving during regular working hours stayed 20 min longer in the ED than during weekend or after-hours: 207 (143–284, $n = 5475$) min versus 187 (127–265, $n = 5243$) min. A similar trend was observed for patients transferred to the medical ICU [141 (85–212, $n = 539$) min and 116 (72–175, $n = 634$) min, respectively] (Fig. 2).

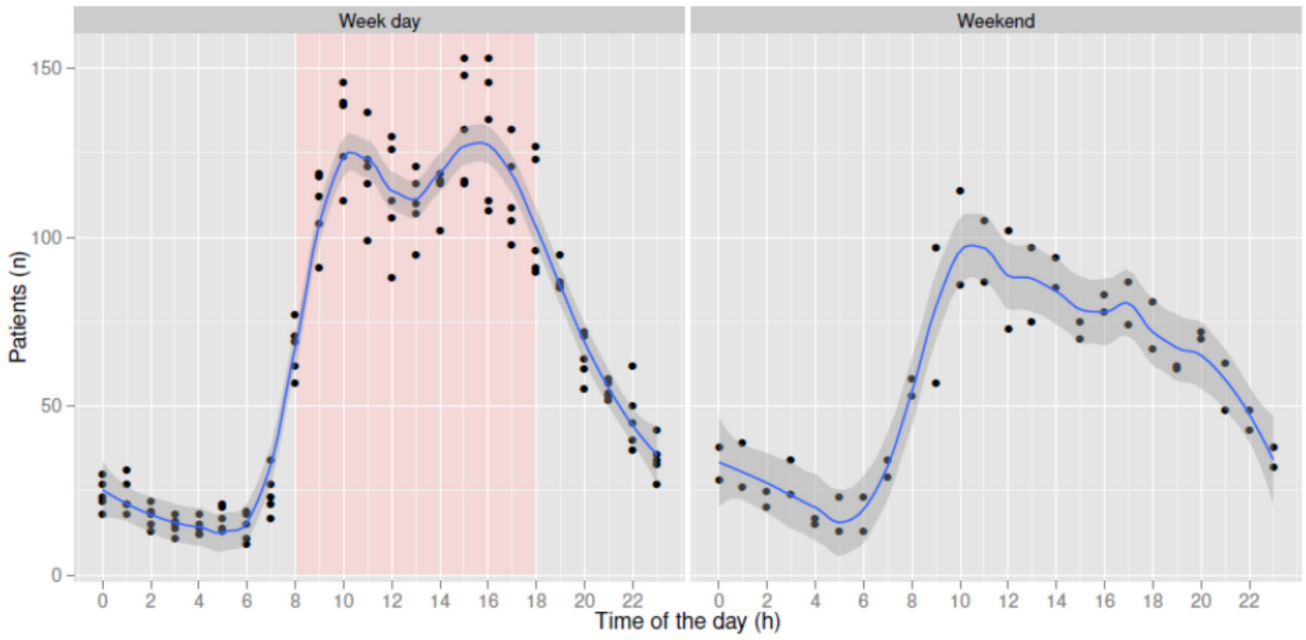
The average LOS in the ED for SRF additionally treated with NIV was 155 min (131–220, $n = 25$) if transferred to the ICU and 165 min (90–230, $n = 38$) to internal wards (Fig. 2). Door to NIV application in the ED was 56 (31–97, $n = 54$) min. NIV was initiated within 15 (10–23.5) min after the RespiCare team was called. Door to ICU outside regular working hours was 84 (57–166, $n = 7$) min. Twelve of 63 patients in the NIV group were intubated, 3 directly in the ED, 4 after a delay of more than 24 h. Fourteen patients died, 9 of these had an AND-order (Fig. 1).

Time to NIV

On average, the RespiCare was called within 15 (0–61) min after the patients arrived in the ED. Call to show-up delay was 7.5 (5–10) min, and NIV was initiated 7.5 (5–13.5) min later, door to NIV was 56 (32–97) min. NIV was delayed in 2 cases: once because of a misunderstanding on the phone, and once because the RespiCare team was in the ED already initiating NIV in another patient who had a higher priority.

Intubation and mortality

The highest mortality rates were observed in patients with an AND-order (9/25) and patients suffering from LRTI (5/11). In patients eligible for unrestricted medical treatment, 5 of 38 died (Fig. 1). Mortality was lower if patients were transferred to the ICU rather than to the peripheral ward (4 of 26 versus 10 of 37). Lower respiratory tract infection (LRTI) was the major single cause for intubations (5 of 12). In patients undergoing NIV in the ED, 12/63 were intubated subsequently (1 within less than 1 h NIV, the other within 48 h), and 16/63 patients died during hospital stay. In the group of patients not treated in the ED, six were treated with NIV in the ICU, two of them were intubated, and two patients died during hospital stay.



	Week days (8 AM - 6 PM)	Week days (6 PM - 8 AM)		Weekend (8 AM - 6 PM)	Weekend (6 PM - 8 AM)
LOS (h) (ICU arrivals)	2.35 (1.42-3.53) (n=591)	1.82 (1.18-2.58) (n=267)	LOS (h) (ICU arrivals)	2.15 (1.23-3.33) (n=210)	2.01 (1.26-3.11) (n=105)
LOS (h) (all arrivals)	3.45 (2.40-4.72) (n=5701)	3.03 (2.03-4.30) (n=2718)	LOS (h) (all arrivals)	3.57 (2.45-4.90) (n=1798)	2.78 (1.92-4.01) (n=940)

Fig. 2 Patient arrival and length of stay (LOS) on the emergency department (ED). From March 1st 2012 until February 28th 2013 10,718 patients were admitted to medical wards including the medical ICUs ($n = 1173$) via the ED. The graph depicts a summary of all 10,718 patients admitted, separated in weekdays (*left*) and weekends (*right*). The *red box* indicates the availability of the RespiCare. The *tables* below the figure depict patient arrival and LOS on ED. *ICU* intensive care unit, *LOS* length of stay (color figure online)

Respiratory parameters

Data reflecting RR and dyspnea were available in 56 of 63 patients undergoing NIV in the ED (Fig. 3). After NIV, RR improved from 30/min (25–35) to 19/min (14–24, $p < 0.001$). In 44 of 56 patients a RR < 25/min was achieved. Dyspnea ($n = 35$) dropped from 7 (5–8) to 2 (0–3) ($p < 0.001$). In 31 of 35 of patients where respiratory rate and dyspnea scale were both available, the treatment goal could be reached. Data reflecting RR for the 16 patients arriving outside the availability of the RespiCare RR were available in 14 cases: RR was 28/min (20–35), dyspnea scores were available in 6 cases; VAS 8 (7–9). Data after treatment in the ICU were not available.

The course of arterial oxygen saturation, arterial carbon dioxide tension, oxygen supply and pH is demonstrated in Fig. 4. The SpO_2 increased from 90 % (84–94) to 93 % (91–95) ($p < 0.01$). Oxygen supply was reduced from 3 (1–6) l/min to 2.5 (1.75–4.5) l/min ($p = 0.063$). In hypercapnic patients ($n = 40$), NIV resulted in an improvement of respiratory acidosis: the pH increased from 7.29 (7.24–7.33) to 7.35 (7.29–7.40) ($p < 0.01$). The $PaCO_2$ decreased from 8.82 (8.13–10.15) kPa to 7.45 (6.60–8.75) kPa ($p < 0.01$). In two patients the $paCO_2$ remained unchanged, in one patient, the respiratory acidosis worsened and intubation was unavoidable.

Hemodynamic parameters

The heart rate decreased from 106 (90–122) to 96 (76–114) bpm ($p < 0.01$). The mean arterial pressure (MAP) changed from 93 (85–104) to 86 (78–96) mmHg ($p < 0.01$). A significant improvement in the MAP from 110 (99–114) to 94 (85–103) mmHg was observed in hypertensive patients (BP > 140/90 mmHg) ($n = 27$), whereas in normotensive patients ($n = 30$) it did not change: 87 (77–93) to 85 (76–89) mmHg. There seemed to be a trend of increasing blood pressure in hypotensive patients ($n = 4$) treated with NIV.

Hospital length of stay

In the group of patients who were treated in the ED, the hospital length of stay was 10 (8–14.5) days in hospital, in the other group 11 (8–12.3) days.

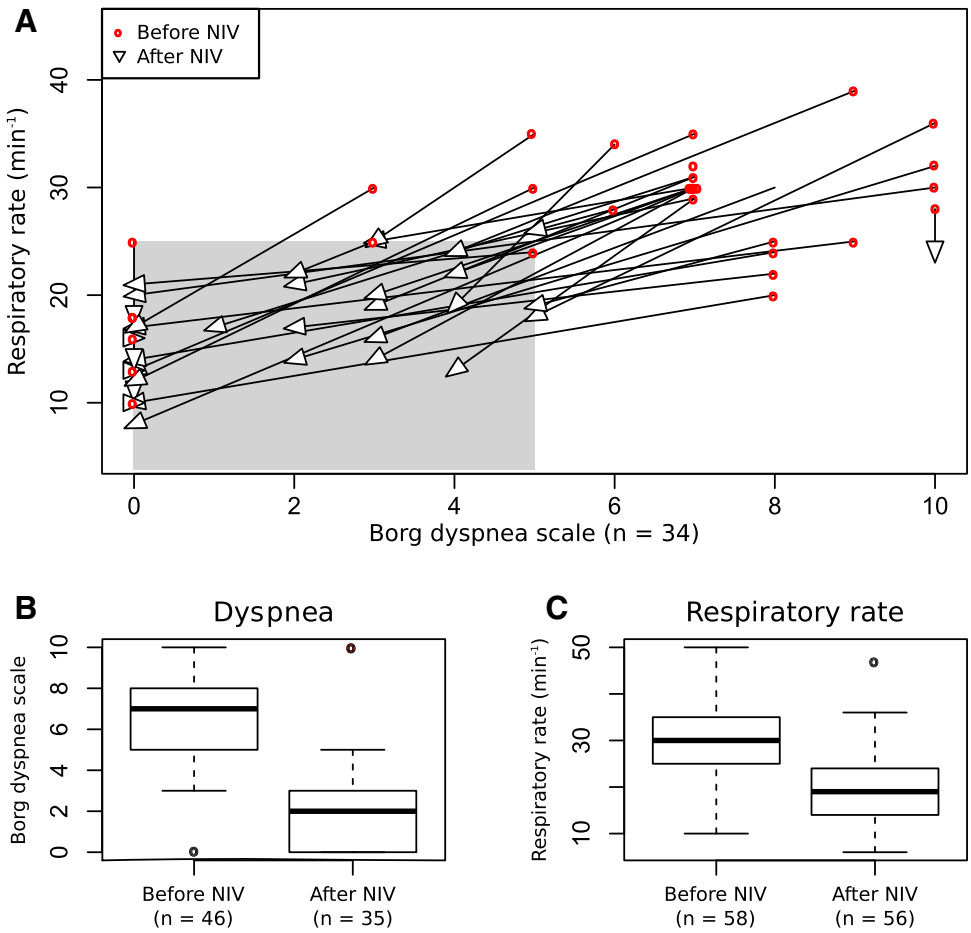


Fig. 3 Dyspnea and respiratory rate. Boxplots with whiskers showing dyspnea (*left*) and respiratory rate (*right*) before and after non-invasive ventilatory support (NIV). In the figure above the *red dots* reflect the values of dyspnea and the correlating respiratory rate before NIV and the *arrows* reflect the changes in dyspnea and respiratory rate (RR) after NIV. The *grey rectangle marks* the area of treatment success (RR < 25/min, Borg dyspnea visual analogue scale <5). *NIV* non-invasive ventilatory support (color figure online)

Discussion

With the present study, we demonstrate that instantaneous NIV is feasible and beneficial in patients with SRF admitted during working hours in a non-university hospital by using preexisting resources. Our immediate failure rate of 2 % compares favorably to immediate failure rates of 15 % recently published [13]. We relate this to our well trained and experienced RTs, which has been shown to be an important factor for NIV success [8]. Immediate NIV in the ED in patients with SRF, improved dyspnea and reduced RR (Fig. 3). Similar findings were observed when NIV was initiated in a pre-hospital setting in patients with COPD [14], or in unselected patients suffering from SRF [15]. The reduction of Borg dyspnea is a unique finding in the ED, and implies that NIV is also a good symptomatic treatment. Moreover, we believe that the Borg visual dyspnea score should be included to measure the success of NIV.

Our NIV strategy neither delayed ICU placements, nor prolonged ED stays. We were able to treat more than 50 % of the SRF patients eligible for NIV during working hours. We cannot entirely exclude that we might have missed patients who would have been eligible for NIV during the off hours of the RespiCare. Nevertheless, our analysis of the patient flow in our Swiss ED (Fig. 2) indicate that most patients arrive during regular working hours, whereas in the national hospital ambulatory medical care survey (NHAMCS) most patients were reported to arrive in the ED after working hours [16]. The average LOS in the ED was approximately 2.5–3.0 h (Fig. 2). In various studies, much longer placement times were documented [11, 17]. Closer to our treatment times, Easter and colleagues reviewed the NHAMCS Database, and calculated a similar LOS for non-invasive ventilated patients of 197 min with even longer stay (224 min) for those being transferred to the ICU [17]. In contrast to their results, our patients transferred to the ICU had a shorter LOS in the ED, maybe secondary to the fact that within 15 min after starting NIV, we reinitiated the placement strategy of the patient.

Mortality rates were highest in patients with an AND-order; Azoulay and colleagues report rates of up to 44 % [18] in this patient category. NIV is not yet implemented in many guidelines for respiratory failure [19], whether or not patients are to be resuscitated. However, the use of NIV in patients suffering from malignancies and hypercapnic

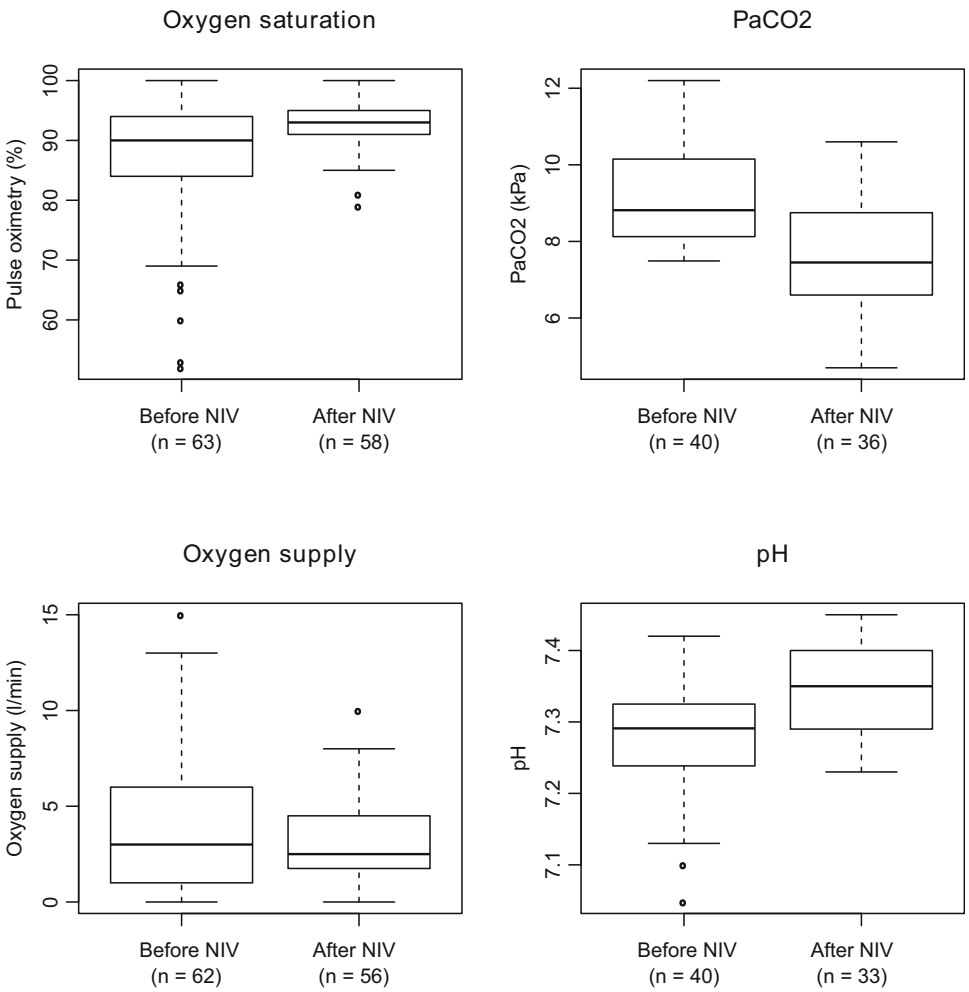


Fig. 4 Parameters for ventilation and oxygenation. Boxplots with whiskers showing arterial oxygen saturation, arterial carbon dioxide tension ($paCO_2$), oxygen supply and pH. *NIV* non-invasive ventilatory support

respiratory failure can be successful, appears to improve dyspnea to a larger extent than morphine, and may thus change the current strategy of treatment [20, 21].

Most studies in patients with SRF focus on the pH, $paCO_2$ and oxygenation, especially in hypercapnic patients, where improvements in the $paCO_2$ and pH have been shown [4]. This may be associated with an amelioration of symptoms, such as tachypnea and dyspnea as observed in this study. Indeed, in type 2 SRF, NIV rapidly reduces $paCO_2$, and increases the pH (Fig. 4). Although we did not include a control group without NIV in our study, improvements in the pH and $paCO_2$ during NIV have been associated with reduced intubation rates, shorter hospital LOS and superior hospital survival [4, 22, 23]. Tomii and colleagues [24] also demonstrate reduced mortality rates and shorter ICU and intermediate care stays in various types of respiratory failure.

It is of note that "AND"-order patients also profited [18, 25], especially patients with SRF type 2 [18, 21].

Patients with type 1 SRF exhibit a marked improvement of dyspnea and RR (Fig. 3). However, outcomes are less favorable in this subgroup, especially in patients with LRTI. This is similar to the results of Jolliet et al., where patients with severe community acquired pneumonia have high rates of mortality (33 %) and intubation (75 %) [26].

Another therapeutic option in these patients has recently emerged: high flow nasal cannula (HFNC) supportive therapy, which seems to be promising especially in acute hypoxemic respiratory failure, is better tolerated, needs less equipment and workload is decreased compared to NIV, but at the moment there are no large randomized controlled trials available to identify patients who would profit most from HFNC [27].

The present study has certain limitations: the study design does not include a control group, and, thus, does not allow proof of a causal relationship between instantaneous initiation of NIV and outcome. It is our feeling that, given the clear clinical benefit of NIV in patients with SRF in the ED, a randomization of patients to a control group would be ethically problematic at this stage.

Furthermore, we might have missed patients who arrived during the night, when the RespiCare team was not

present, and our dataset is not complete for some patients with respect to dyspnea and respiratory rates. We decided not to compare but just to report on patients who arrived outside regular working hours and during working hours, since this data might be heavily biased, because we did not implement a severity of disease classification. Moreover, in these patients, other NIV machines were used with other settings that could have biased the findings as well. In addition, the relatively small number of patients in the group who were treated with NIV outside regular working hours would have limited the impact of statistical findings. The transferability of our findings to other hospitals is therefore limited.

Conclusion

In patients with SRF of varying origin, instantaneous NIV in the ED during regular working hours is feasible in a non-university hospital setting, and rapidly and significantly alleviates dyspnoea and reduces respiratory rate. This approach is useful as a bridge to the ICU as well as an efficient palliative dyspnoea treatment.

Despite restriction to regular daytime working hours, NIV could be offered to >50 % of patients, and it neither prolongs LOS in the ED, nor delays ICU-placement. Limiting NIV in the ED to restricted hours may help to introduce NIV in hospitals with few resources. Since patient arrivals differ from hospital to hospital and from country to country, it is necessary to assess when demand for NIV is highest, and then setup the NIV service accordingly.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Statement of human and animal rights The local ethics committee approved the anonymous publication results (EKSG 13/118).

Informed consent Informed consent was waived due to the retrospective nature of the study.

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