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NT-PROBNP SERUM CONCENTRATIONS IN SURGICAL CRITICALLY ILL PATIENTS WITH NON-SEPTIC AND SEPTIC SHOCK

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ABSTRACT

Background: Cardiovasculatory dysfunction occurs in surgical critically ill patients with shock. The degree of cardiovasculatory dysfunction in the Sequential Organ Failure Assessment (SOFA) score increases with higher catecholamine infusion rates. The aim of the present study was to compare the course of NT-proBNP plasma concentrations in surgical critically ill patients with non-septic or septic shock in association with catecholamine therapy.

Methods: In a prospective observational single-centre study in critically ill surgical patients admitted to an University adult ICU, 26 consecutive patients with non-septic shock and 18 patients with septic shock were longitudinally monitored before, during and after shock.

Results: During the stay on the ICU, NT-proBNP serum concentrations declined, remained stable or increased in both shock groups. The maximal NT-proBNP concentrations in patients with septic shock (median 4,429, range 193 to > 35,000 pg/ml) were higher than in those with non-septic shock (median 902, range 39 to > 31,937 pg/ml) ($p = 0.037$). NT-proBNP serum concentrations were higher in surviving patients with septic than with non-septic shock at > 0.1 and ≤ 1.0 ug/kg/min noradrenaline. In the non-survivors, NT-proBNP concentrations were always beyond the normal range in both groups.

Conclusions: Taken together, severity of cardiovascular dysfunction defined by higher dosage of catecholamines is associated with higher NT-proBNP concentrations in septic than in non-septic shock patients. In non-survivors of shock, NT-proBNP concentrations increase or remain elevated > 1000 pg/ml.

INTRODUCTION

After severe trauma or major surgery in systemic inflammatory response syndrome (SIRS) and in severe sepsis, patients are at high risk to develop shock and multiorgan dysfunctions, including cardiovascular and myocardial dysfunction, due to impaired perfusion, decreased oyxgen supply and ischemia / reperfusion injury, associated with a high mortality rate [1-5]. In the current sepsis definitions [6], myocardial depression has been included in the definition of severe sepsis. An impaired left ventricular systolic function may occur in more than 50% of patients with severe sepsis and septic shock [7]. In the Sequential Organ Failure Assessment (SOFA) score [8], worsening of cardiovasculatory dysfunction is reflected by higher catecholamine infusion rates, such as noradrenaline.

Natriuretic peptides may serve to evaluate and quantify cardiac dysfunction in patients with sepsis [7]. B-type natriuretic peptide (BNP) gene expression can increase very rapidly [7]. An advantage of NT-proBNP over BNP as a marker of myocardial depression in SIRS and sepsis might be its longer half-life (NT-proBNP half-life, 2h; BNP half-life, 20 min) [9]. NT-proBNP values at 72 hours after development of severe sepsis and septic shock were an independent predictor of hospital mortality [10]. Beyond left ventricular filling pressures, other stimuli might account for BNP release, including right ventricular strain, renal failure, cytokine up-regulation, and catecholamine therapy [7]. However, data on cardiovascular dysfunction in association with catecholamine therapy and NT-proBNP in patients with SIRS and sepsis are sparse.

AIMS AND OBJECTIVES

Therefore, the present longitudinal study reflecting severity of cardiovascular dysfunction by the dosage of noradrenaline according to the definitions of the SOFA score [8] was performed in surgical critically ill ICU patients with non-septic or septic shock to clarify the following questions:

Do NT-proBNP serum concentrations differ:

1. between non-septic and septic shock patients regarding dosage ranges of catecholamines?
2. between survivors and non-survivors of non-septic / septic shock?
3. within non-septic and septic shock patients regarding dosage ranges of catecholamines and ICU course?

Research hypotheses:

NT-proBNP serum concentrations will be higher: 1. with greater dosages of catecholamines within the groups of non-septic and septic shock patients; 2. in septic shock than in non-septic shock patients; and 3. in non-survivors than in survivors of non-septic / septic shock.

PATIENTS AND METHODS

***Patients and data collection*:** A prospective observational single-centre study in surgical critically ill patients admitted to an University adult ICU has been performed. The study is in compliance with the Helsinki declaration and was approved by the Independent Human Subjects Review Board Ethics Commission of the University Ulm (approval number 114/07) (ClinicalTrials.gov ID: NCT00736723). From 08/2008 to 12/2008, all admissions were surveyed daily computer-assisted regarding sepsis and shock. Patients who were admitted to the Anaesthesiology adult ICU or developed non-septic or septic shock on this ICU between July 2008 and December 2008 were included in the present study and were longitudinally monitored. Patients were admitted to the Anaesthesiology ICU of the University Hospital Ulm after major trauma, vascular, lung, brain or abdominal surgery.

All surgical patients admitted to this ICU were routinely computer-assisted surveyed for severity of disease and of organ dysfunctions, and presence of sepsis, on a daily basis. Severity of disease on admission was monitored by the Simplified Acute Physiology Score 3 (SAPS 3) [11], the Simplified Acute Physiology Score II (SAPS II) [12] and the Acute Physiology and Chronic Health Evaluation Score II (APACHE II) [13]. Severity of organ dysfunctions were assessed by the Sequential Organ Failure Assessment (SOFA) score [8] on a daily basis. Sepsis was defined using the 2003 SCCM/ESICM/ACCP/ATS/SIS sepsis definitions [14]. Severe sepsis was defined as sepsis plus organ dysfunction [14]. Organ dysfunctions regarding sepsis were defined according to the limitations for organ dysfunction variables and tissue perfusion variables (hyperlactatemia) as given in the original publication [14]. Septic shock was defined as sepsis plus shock [14]. Shock was defined as hypotension despite adequate volume resuscitation, a systolic blood pressure of ≤ 90 mmHg, or the need of vasopressors to keep blood pressure ≥ 90 mmHg. Only cases ≥ 18 years were selected for the present evaluation because SAPS II score [12] and the 2003 SCCM/ESICM/ACCP/ATS/SIS sepsis definitions [14] have been developed for patients ≥ 18 years, and the SOFA score [8] for patients ≥ 12 years.

Blood Samples: To take into account the severity of the cardiovascular dysfunction, blood samples were taken on the first day with severe SIRS or sepsis, and following according to intravenous nor-adrenaline and adrenaline dosages (Table I). In both, in non-septic shock and septic shock, nor-adrenaline and adrenaline were applied to counteract myocardial dysfunction and hypotension, caused by haemorrhage, hypovolemia or dilation of the peripheral vascular system, promoted by inflammatory cytokines and microbial toxins in sepsis or during reperfusion-injury. The cut-off values in the SOFA score [8] for dosages of nor-adrenaline and adrenaline needed to provide a sufficient mean arterial pressure were used to assess the degree of cardiovasculatory dysfunction. In the SOFA score [8], organ failure assessment of the cardiovascular system is reflected with 1 point with a mean arterial pressure < 70 mmHg, 2 points with dopamine < 5 ug/kg/min or dobutamine at any dose, 3 points with dopamine > 5 ug/kg/min, noradrenaline or adrenaline ≤ 0.1 ug/kg/min, and at maximum, with 4 points with dopamine > 15 ug/kg/min, noradrenaline or adrenaline > 0.1 ug/kg/min necessary to maintain an adequate mean arterial pressure. Blood was drawn from arterial lines, routinely placed for invasive blood pressure measurements and blood gas analyses in the patients. Samples were immediately centrifuged and plasma was stored at -20 °C until testing. According to the limits of the SOFA score regarding cardiovasculatory dysfunction, blood samples were taken at the time points given in Table I, to determine NT-proBNP serum concentrations.

Table I: Time schedule for drawing blood samples

		Noradrenaline dose (ug/kg/min)
Septic / non-septic shock	First day of severe SIRS/sepsis	0
	First day of shock	> 0 and ≤ 0.1 > 2 h
	First day of shock	> 0.1 and ≤ 1.0 > 2 h
	First day of shock	> 1.0 > 2 h
	First day of shock	> 1.0 + adrenaline > 2 h
	First day after shock	0
Survivors	Before demission from ICU	0
Deceased	Before death	

NT-proBNP: NT-proBNP serum concentrations were determined by a fully automated "sandwich" electrochemiluminescence immunoassay (ECLIA) using a Roche Elecsys 2010 analyzer (Roche Diagnostics, Basel, Switzerland) according to the prescriptions of the manufacturer. The assay uses two polyclonal antibodies, a biotinylated capture antibody recognizing the first 20 N-terminal amino acids of NT-proBNP and a ruthenium derivative labeled antibody binding to amino acids including positions 40-50. Streptavidin labelled microparticles were added to the samples containing the antibody-NT-proBNP complex, thus binding it to the solid phase via biotin-streptavidin interaction.

The 95th percentile for NT-proBNP concentrations in 18 – 44 year old adults was 97 pg/ml and for adults in the age > 75 years 526 pg/ml [15]. Cut-off values for increased cardiac risk of 125 pg/ml have been reported for primary care patients with suspected chronic heart failure [16] and for symptomatic patients with underlying cardial dysfunctions [17].

Statistical analyses: For continuous variables, the median and range are reported, whereas for categorical variables, the number of patients in each category is given. Statistical analysis between groups (Mann-Whitney-U test for categorical values and Fisher's excat test for nominal variables) was performed with GraphPad Prism version 5

(GraphPad Software, San Diego, USA). Differences were considered as statistically relevant with $p < 0.05$.

RESULTS

Patient characteristics: A total of 373 critically ill surgical patients were admitted from 01 July 2008 to 31 Dec 2008 in the ICU and were surveyed daily using computer-assistance with respect to sepsis, organ dysfunctions assessment and shock [14]. 51 cases ≥ 18 years with shock were included in this study. Four patients of the non-septic shock group and three patients of the septic shock group had to be excluded from further analysis, due to refusal of informed consent, stay < 24 hours on the ICU, early demission to another ICU or concomitant cardiogenic shock. Thus, for evaluation, this study included 44 critically ill shock patients recruited between July 2008 and December 2008, with 26 patients in the non-septic shock group and 18 patients in the septic shock group (Table II).

Table II: Patient demographics and characteristics of the non-septic and septic shock group

							Microorganisms		
Nr.	Sex	Age	Death	HDF	Diagnosis	Surgery	Gram pos.	Gram neg.	Anaerobs
Non-septic shock patients									
1	f	77	0	0	Ovarial tumor	Resection tumor, sigma			
3	m	42	0	0	Polytrauma	Osteosyntheses			
7	m	46	0	0	Polytrauma	Osteosyntheses			
8	f	73	1	1	Rupture of thoraco-abdominal aortic aneurysm	Aortic prothesis, stent			
10	m	57	0	0	Bronchial carcinoma	Resection of segments 4, 5			
12	m	20	0	0	Traumatic rupture of liver	Abdominal packing, suture			
14	m	59	0	0	Esophageal tumor	Esophageal resection			
21	m	77	0	0	Thoracic haematoma	Haematoma removal			
25	f	21	0	0	Bronchial break off	Pneumectomy			
27	m	39	0	0	Polytrauma, traumatic brain injury	Osteosyntheses			
31	f	73	0	0	Bleeding from abdominal anastomosis	Reanastomosis			
32	m	71	1	1	Bleeding duodenal ulcer	Suture			
33	f	46	1	0	Traumatic brain injury, lung contusion	Drainage			
35	m	46	0	0	Aortoduodenal bleeding	Stent			
36	m	21	0	0	Haemorrhagic pneumothorax, fracture face bones	Reconstruction face bones			
37	m	47	0	0	Polytrauma	Aortic stent			
39	m	44	0	0	Polytrauma, fracture of acetabulum, traumatic brain injury	Osteosyntheses			
40	m	81	0	0	Retroperitoneal haematoma	Haematoma removal			
43	m	71	0	0	Aortic aneurysm	y-prothesis			
44	m	39	0	0	Bleeding gastric ulcer Forrest Ia	Suture			
45	m	36	0	0	Intracranial bleeding multiple fractured skull	Osteosyntheses			
46	f	60	0	0	Lung tumor	Resection lower lobe			
48	m	68	0	0	Ileus	Adhesiolysis			
50	m	49	0	0	Polytrauma, traumatic brain injury	Osteosyntheses			
51	m	69	0	0	Gastric tumor	Gastrectomy			
52	f	78	0	0	Retroperitoneal haematoma	Haematoma removal			
Septic shock patients									
2	m	45	0	1	Infected shoulder	Arthroscopy	X		
4	m	57	0	0	Perforation of sigma	Anus praeter	X	X	
5	m	54	0	0	Polytrauma	Osteosyntheses		X	
6	m	38	0	0	Ischemic bowel by occlusion arteria mesenterica superior	Vessel bypass	X	X	
9	m	66	0	0	Near-by drowning	Caecal fistula		X	
11	m	69	0	1	Carnifying Pneumonia	Resection of lower lobe		X	
13	m	37	0	0	Phlegmone neck	Cervical drainage			X
15	m	52	0	0	Infected retroperitoneal tumor	Tumor resection	X	X	
17	m	51	1	1	Abscess lower leg	Muscle resection	X		
19	m	68	1	0	Perforation of jejunum	Segment resection	X	X	
20	m	71	0	1	Infected abdominal aortic aneurysm	Aortic prothesis	X		
23	m	89	0	0	Gastric perforation	Suture	X	X	
26	m	54	0	0	Acute oedematous pancreatitis	No		X	
29	m	68	0	0	Necrotizing pancreatitis	Necrosectomy cholecystectomy		X	
34	m	73	1	1	Acute oedematous pancreatitis	Necrosectomy	X	X	
38	f	68	0	0	Ileus, anus praeter break off	Anus praeter reoperation		X	
41	f	38	0	0	Necrotizing pancreatitis	Necrosectomy		X	
42	m	63	0	1	Incarceration of hernia	Herniotomy	X		

Patient's characteristics and scores are summarized in Table III. Age, sex ratio, renal replacement therapy, maximal noradrenaline dose, SOFA score, SAPS 3 score, APACHE II score, and ICU death rate in the non-septic and in the septic shock group were comparable. The majority of patients in both groups were male.

Table III: Comparison of patient characteristics and scores between the non-septic and septic shock group

	Total (n=44)	Non-septic shock (n=26)	Septic shock (n=18)	Non-septic shock vs. septic shock p =
Age, years	57 (20-88)	53 (20-81)	60 (37-88)	0.702
Male/female	35/9	19/7	16/2	0.270
Stay on ICU, days	9 (2-52)	8 (3-52)	12 (2-34)	0.666
Renal replacement therapy	9 (21%)	3 (12%)	6 (33%)	0.128
Maximal noradrenaline dose (ug/kg/min)	0.185 (0.01 -3.83)	0.13 (0.01 – 3.83)	0.21 (0.03 – 1.72)	0.310
SOFA score[1]	9 (3-18)	8 (3-15)	9 (5-18)	0.348
SAPS 3 score[2]	45 (24-87)	47 (26-87)	43 (24-87)	0.458
APACHE II score[2]	20 (10-45)	23 (10-45)	18 (11-37)	0.162
Deceased on ICU	5 (11%)	2 (8%)	3 (17%)	0.386

[1] highest value during ICU stay; [2]value on admission to ICU. Data are given as median values with the range in brackets.

NT-proBNP:

NT-proBNP non-septic vs. septic shock: The maximal NT-proBNP concentrations in patients with septic shock (median 4,429, range 193 to > 35,000 pg/ml) were higher than in those with non-septic shock (median 902, range 39 to > 31,937 pg/ml) (p = 0.037). NT-proBNP concentrations were higher in survivors of septic shock than in those of non-septic shock in the > 0.1 and ≤ 1.0 ug/kg/min noradrenaline groups, and before demission from the ICU (Table IV).

Table IV: NT-proBNP concentrations in survivors and non-survivors of non-septic (N) or septic shock (S). A = adrenaline, NA = noradrenaline. Time points are: NA 0 = no noradrenaline, NA ≤ 0.1, NA > 0.1 = NA > 0.1 and ≤ 1.0, NA > 1.0, NA/A = > 1.0 ug/kg/min noradrenaline plus adrenaline, post = after shock, dms = before demission from ICU, death = before death. Dotted lines represent normal range. *p < .05.

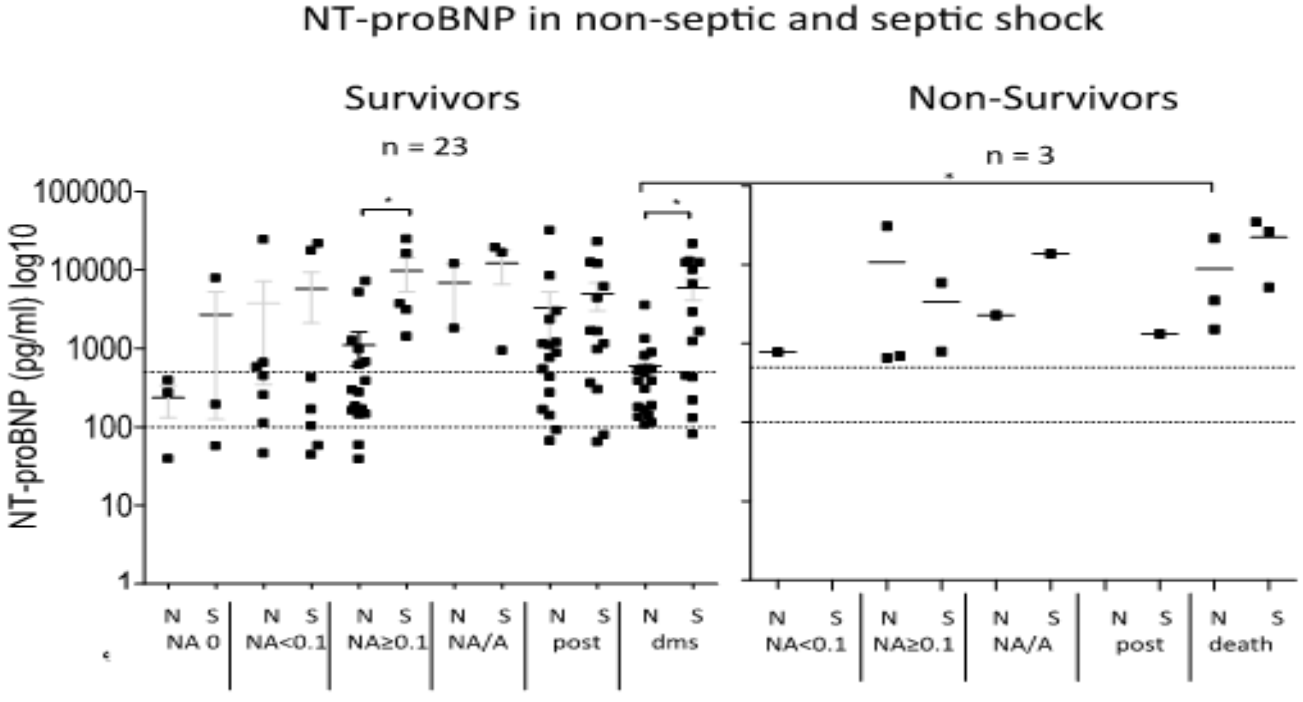
None of the five survivors of septic shock and of the 16 survivors of non-septic shock in the > 0.1 and ≤ 1.0 ug/kg/min noradrenaline group, was on renal replacement therapy at the timepoint of measurement. In the further course, none of the non-septic shock survivors, however 3/5 of the septic shock survivors developed need for renal replacement therapy.

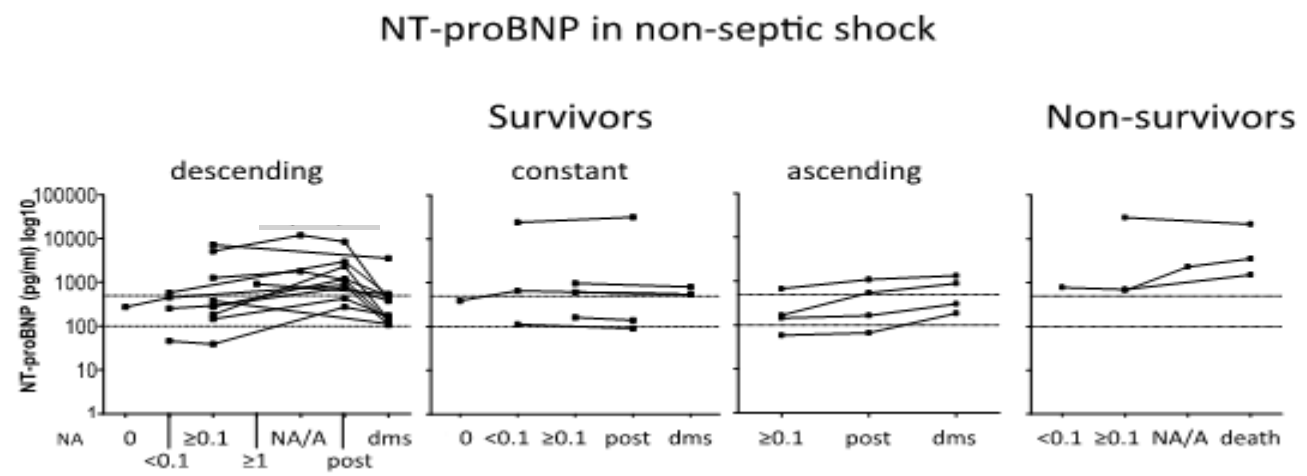
NT-proBNP non-septic shock survivors vs. non-survivors: NT-proBNP concentrations were higher in non-survivors of non-septic shock before death than in survivors before demission from ICU (Table IV).

NT-proBNP septic shock survivors vs. non-survivors: There were no differences in NT-proBNP concentrations in non-survivors of septic shock and in survivors at all time points (Table IV).

NT-proBNP non-septic shock patterns: According to noradrenaline dose and ICU course, NT-proBNP concentrations were descending (in 18% of patients), constant (27%) or ascending (55%) in the survivors of non-septic shock, and continuously elevated or ascending in the non-survivors (Table V). In the non-survivors, NT-proBNP concentrations were always beyond the normal range.

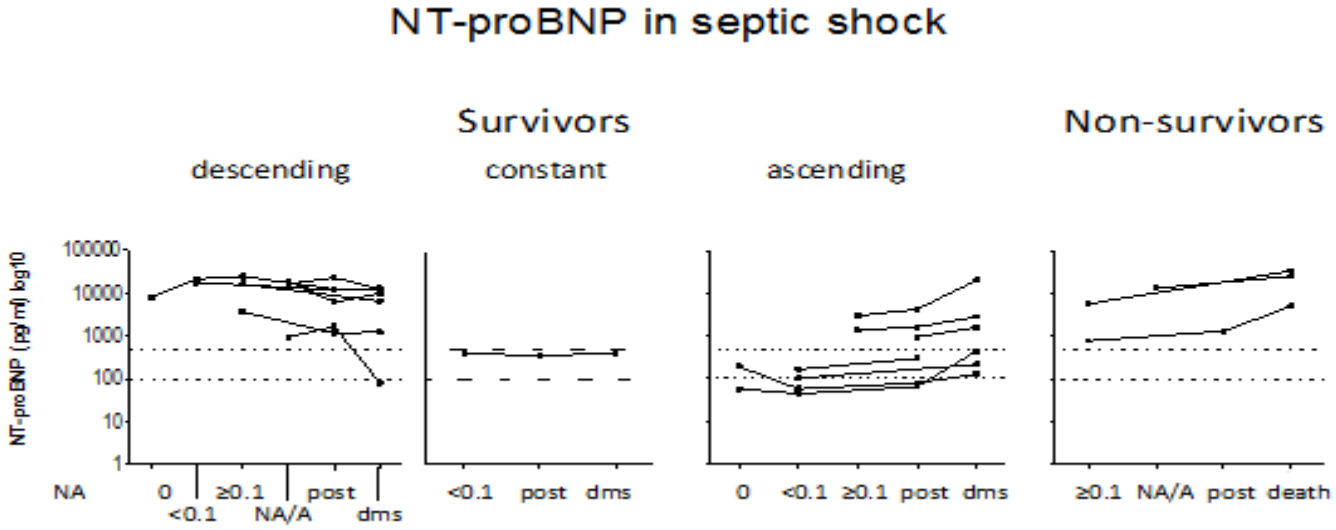
Table V: NT-proBNP concentrations in survivors and non-survivors of non-septic shock. A = adrenaline, NA = noradrenaline. Time points are: NA 0 = no noradrenaline, NA ≤ 0.1, NA > 0.1 = NA > 0.1 and ≤ 1.0, NA > 1.0, NA/A = > 1.0 ug/kg/min noradrenaline plus adrenaline, post= after shock, dms = before demission from ICU, death = before death. Dotted lines represent normal range.





NT-proBNP septic shock patterns: According to noradrenaline dose and ICU course, NT-proBNP concentrations were descending (in 47% of patients), constant (6%) or ascending (47%) in the survivors of septic shock, and continuously ascending in the non-survivors (Table VI). In the non-survivors, NT-proBNP concentrations were always beyond the normal range.

Table VI: Patterns of NT-proBNP concentrations over time in survivors and non-survivors of septic shock. A = adrenaline, NA = noradrenaline. Time points are: NA 0 = no noradrenaline, NA ≤ 0.1, NA > 0.1 = NA > 0.1 and ≤ 1.0, NA/A = > 1.0 ug/kg/min noradrenaline plus adrenaline, after shock, dms = before demission from ICU, death = before death. Dotted lines represent normal range.



DISCUSSION

The main results of the present study regarding the type of shock are that the maximal NT-proBNP concentrations in patients with septic shock were higher than those in non-septic shock. Moreover, NT-proBNP concentrations were higher in survivors of septic shock than in those of non-septic shock in the > 0.1 and ≤ 1.0 ug/kg/min noradrenaline range, and before demission from the ICU. Regarding patterns according to noradrenaline dose and ICU course, NT-proBNP concentrations were ascending, constant or descending in the survivors of both groups, and continuously elevated or ascending in the non-survivors. In the non-survivors, NT-proBNP concentrations were always beyond the normal range in both groups.

Limitations: Our study has several limitations. In the present study, severity of cardiovascular dysfunction has been defined according to the cut-off values for catecholamines given in the SOFA score [8]. Thereby, the patients' blood probes were collected at comparable timepoints of cardiovascular dysfunction, however, at different time points during the ICU stay. Moreover, myocardial depression has not been verified in our patients by a low cardiac index or by echocardiography.

Noradrenaline dose and NT-proBNP: We expected higher NT-proBNP levels in patients with higher noradrenaline dose, with the hypothesis that higher noradrenaline dose reflects more severe cardiovascular dysfunction. Comparing patients with non-septic and septic shock, in the > 0.1 and ≤ 1.0 noradrenaline dose range as a surrogate marker of severe cardiovascular dysfunction, NT-proBNP levels in the septic shock patients were markedly higher than in the non-septic shock patients (Table IV). This may be explained in a way that in septic shock more myocardial depressant factors, such as tumor necrosis factor (TNF-α), interleukin 1ß (IL-1ß) and IL-6 [7], are released than in non-septic shock leading to a greater counterregulatory increase in NT-proBNP concentrations. However, regarding increasing noradrenaline dose in both shock groups, NT-proBNP concentrations were ascending, constant or descending in the survivors (Table V and VI). The preferred vasopressor used to treat patients with septic shock is noradrenaline [18], which is a predominantly α-receptor agonist with systemic and pulmonary vasoconstrictor properties [19]. However, in patients with septic shock, noradrenaline has been shown even to enhance cardiac index due to its ß-adrenergic

properties [19], and, thus, might lead to an overestimation of the true left ventricular systolic function. Thus, improved myocardial function may have contributed to the descending patterns of NT-proBNP levels despite higher noradrenaline dose in the present study.

Cardiac dysfunction and NT-proBNP: The ascending NT-proBNP levels in our non-survivors in both groups until death may reflect ongoing cardiac dysfunction. In patients with sepsis, NT-proBNP levels were higher in non-survivors and correlated well with an increase in troponin I levels [20]. However, it remains unclear, whether an increase in NT-proBNP values reflects sepsis associated cardiac dysfunction [21]. In two cases of sepsis, markedly elevated NT-proBNP levels were not indicative of depressed myocardial function [22]. Despite much lower cardiac indices in patients with acute heart failure (2,2 l/min) compared to patients with severe sepsis and septic shock (4,6 l/min), there were no differences in NT-proBNP levels [23]. In these cancer patients with septic shock, repeated transthoracic echocardiographs showed that NT-proBNP on day 2 after admission was higher in patients presenting with cardiac dysfunction, whereas NT-proBNP on day 1 did not predict cardiac dysfunction [24]. It was suggested that after an initial overexpression of NT-proBNP in all septic patients, patients with cardiac dysfunction will present persistent high levels of NT-proBNP [24]. In anology, the ascending NT-proBNP levels in our non-survivors of septic shock may reflect ongoing cardiac dysfunction.

Renal failure and NT-proBNP: Renal dysfunction occurs very rapidly and often in patients with sepsis. In the present study, renal dysfunction necessitating renal replacement therapy with hemodiafiltration was not different in patients with septic shock (6/18, 33%) compared to those with non-septic shock (3/26, 12%). Thus, renal replacement therapy cannot explain the higher NT-proBNP levels in the septic patients' group than in the non-septic patients' group. The higher NT-proBNP concentrationes in the survivors of septic shock than in those of non-septic shock in the > 0.1 and ≤ 1.0 ug/kg/min noradrenaline group are not explained by differences in hemodiafiltration, since none of these patients was on hemodiafiltration at the timepoint of measurement. It has been reported that NT-proBNP is markeldy influenced by renal dysfunction. Whereas mild to moderate renal dysfunction lead to 2-fold increase in NT-proBNP in the absence of severe left ventricular dysfunction (LVD), increases were > 4-fold in subjects with severe LVD [25]. Thus, adjusting cut-off values according to renal function was suggested. Proposed binary cut-off values for NT-proBNP were 100 pg/ml for subjects without and 350 pg/ml for subjects with renal dysfunction (glomerular filtration rate < 85 ml/min) [25].

Prognosis / Outcome and NT-proBNP: In patients with septic shock, within 6 hours of admission to the ICU, markedly elevated levels of NT-proBNP have been detected [26]. NT-proBNP levels at admission and after 72 hours were significantly higher in hospital non-survivors of severe sepsis and septic shock compared with survivors [10]. In an unselected cohort of critically ill patients admitted to a mixed surgical and medical ICU, a single measurement on ICU admission provided important prognostic information, particularly, if NT-proBNP was ≤ 945 pg/ml [27]. Our data support this limit of around 1000 pg/ml in that all non-survivors had continuously higher levels than around 1000 pg/ml, and most survivors of the non-septic group (15/26) and some patients of the septic shock group (5/18) displayed always levels below this limit (Table V and VI). Regarding prognostic cut-offs, septic patients with NT-proBNP levles > 1400 pmol/l were 3.9 times more likely to die from sepsis [28]. In patients with severe sepsis and septic shock, the best cut-off value for hospital mortality of NT-proBNP at admission was 7090 pg/ml [10].

In our study, only some survivors in both groups yielded comparable and even higher maximal NT-proBNP levels during the observation period than the non-survivors (Table V and VI). This is in agreement with a previous study demonstrating that the median maximal NT-proBNP levels in non-survivors were higher than in the survivors of septic shock [9]. In this study, the NT-proBNP level was higher in non-survivors than in survivors of septic shock at each time between study inclusion and day 7 [9]. On the other hand, descending or low NT-pro BNP levels during ICU stay may indicate good prognosis. Survivors of septic shock displayed a reversibly impaired left ventricular ejection fraction (LVEF), substantially increased left ventricular end-diastolic and end-systolic volumes, and thus, preserved stroke volumes despite impaired LVEF, normalizing within 10 days after onset of septic shock [29]. Thus, the descending NT-proBNP concentrations in our survivors in both groups until demission from ICU may reflect as a surrogate marker of improving cardiac function (Table V and VI). Moreover, persistently low levels < 1000 pg/ml may indicate good prognosis in patients with non-septic or septic shock.

In the future, cut-off values of NT-proBNP in association to catecholamine dosage ranges, cardiac dysfunction and outcome in defined subgroups of patients have to be clarified.

CONCLUSIONS

The present study reveals that longitudinal NT-proBNP measurement may be helpful to differentiate between survivors and non-survivors of non-septic or septic shock. Persistently high or ascending NT-proBNP levels > 1000 pg/ml may indicate poor prognosis, whereas descending or persistently < 1000 pg/ml levels beneficial prognosis in surgical patients with non-septic or septic shock.

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