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The Occurrence and Spreading of Paranasal Sinus Changes among Critically Ill Patients Undergoing Invasive Ventilation: An Observational Cohort Study

Miia M. Jansson^{1*}, Jaana M. Karhu², Lauri Ahvenjärvi³, Timo J. Autio⁴, Hannu P. Syrjälä⁵, Tero I. Ala-Kokko²¹Research Group of Medical Imaging, Physics and Technology, University of Oulu, Oulu, Finland²Division of Intensive Care, Department of Anesthesiology, Oulu University Hospital, Oulu, Finland³Department of Diagnostic Radiology, Oulu University Hospital, Oulu, Finland⁴Department of Otorhinolaryngology and Head and Neck Surgery, Oulu University Hospital, Finland⁵Department of Infection Control, Oulu University Hospital, Oulu, Finland***Corresponding author:** Miia M. Jansson, Postdoctoral researcher, Research Group of Medical Imaging, Physics and Technology, University of Oulu, Oulu, Finland**Citation:** Jansson MM, Karhu JM, Ahvenjärvi L, Autio TJ, Syrjälä HP, et al. (2020) The Occurrence and Spreading of Paranasal Sinus Changes among Critically Ill Patients Undergoing Invasive Ventilation: An Observational Cohort Study. Infect Dis Diag Treat 4: 137. DOI:10.29011/2577-1515.100137.**Received Date:** 20 January, 2020; **Accepted Date:** 11 February, 2020; **Published Date:** 14 February, 2020**Abstract**

Background: The development of ventilator-associated pneumonia could be prevented in the nasotracheally intubated patients by a systematic search for and treatment of nosocomial sinusitis. However, the spreading of paranasal sinus changes with time is poorly defined.

Purpose: To evaluate the occurrence and spreading of paranasal sinus changes among critically ill patients undergoing invasive ventilation in order to evaluate the association between paranasal changes and Intensive Care Unit (ICU)-related outcomes.

Material and methods: This prospective, observational, single-center cohort study was conducted in a single tertiary-level teaching hospital in Finland during 2014-2015. All invasively ventilated adult patients referred for head computed tomography or magnetic resonance imaging scans from October 2014 to June 2015 were eligible for enrolment and monitored daily until discharge from the ICU or death.

Results: During the study period, 6.8% (5.7 per 1,000 patient days) of patients had major findings in their maxillary, 20.3% (18.5 per 1,000 patient days) in sphenoidal, 6.8% (5.7 per 1,000 patient days) in ethmoidal, and 3.4% (2.9 per 1,000 patient days) in frontal sinuses. The spreading of paranasal sinus changes doubled in time. In addition, radiographically proved accumulation of fluid was within 39.0%, 35.6%, and 8.6% of maxillary, sphenoidal, and frontal sinuses, respectively. We found no association between ICU-related outcomes and paranasal sinus changes.

Conclusion: Paranasal sinus changes were common and progressive among critically ill patients undergoing invasive ventilation, without unfavourable impact on ICU-related outcomes.

Keywords: Mechanical ventilation; Surveillance; Ventilator-associated sinusitis

Introduction

Sinusitis is inflammation of the paranasal sinuses and nasal cavity resulting in symptoms such as thick nasal mucus, a plugged

nose, fever, and headache. It affects annually 10 - 30% of people in the United States and Europe resulting in more than US\$11 billion annual costs [1]. The unnecessary and ineffective management of viral sinusitis is common [1,2].

Ventilator-associated sinusitis (VAS) is the third or fourth most frequent Intensive Care Unit (ICU)-acquired infection [3,4].

VAS is caused by gram-negative bacteria, such as *Pseudomonas aeruginosa* (25.0-30.7%), *Proteus mirabilis* (15.4-27.5%), *Acinetobacter baumannii* (23.1-27.5%), and *Klebsiella pneumoniae* (24.1%) [4-6]. The occurrence of VAS (7.7-82.7%) is often underestimated, and the infection is frequently underdiagnosed due to diagnostic difficulties resulting from the lack of clinical signs and standard diagnostic criteria [4-9]. The known risk factors for VAS are continuous sedation [4], duration of endotracheal intubation [7] and mechanical ventilation [4,10], presence of nasogastric tube [4,5,7], supine positioning [4], and head injury [10].

Based on evidence from Computed Tomography (CT) scans, VAS has been associated with frequent involvement of the sphenoid (93.1%), ethmoid (72.4%) and/or frontal (44.8%) sinuses [3], and the infection may lead to sepsis and septic shock [4,7], intracranial infections [11], bacteraemia [12-14], thoracic empyema [15] and secondary infections [5]. In addition, VAS seems to be associated with a fourfold increased risk of ventilator-associated pneumonia (VAP); the proportion of identical pathogens in sinuses and respiratory tract secretions has varied from 38.0% to 60.0% in the cases studied [7,8,12].

During the last decades, scientific interest has almost constantly focused on community-acquired pneumonia [16] and most recently Ventilator-Associated Events (VAEs) [17]. It has been suggested, however, that the development of VAP could be prevented in the nasotracheally intubated patients by a systematic search for and treatment of nosocomial sinusitis [6]. The CT findings such as signs of secretion or mucosal swelling in paranasal sinuses may reflect inflammatory changes, which are believed to be related to the pathogenic process of acute rhinosinusitis in outpatients [18]. Currently, however, the spreading of the CT findings changes with time in patients with orotracheal intubation is poorly defined.

The study is a part of a larger research project that evaluates the incidence and risk factors for VAEs [19-21]. This article, however, focuses solely on the occurrence and spreading of paranasal sinus among critically ill patients undergoing invasive ventilation in order to evaluate the association between paranasal changes and ICU-related outcomes. Thus, all invasively ventilated adult patients referred for head CT or Magnetic Resonance Imaging (MRI) scans from October 2014 to June 2015 were eligible for enrolment and monitored daily until ICU discharge or death. The decision to perform CT/MRI scanning based on the clinical purposes and the sinusitis was not suspected primarily.

Material and Methods

Setting

This prospective, observational, single-center cohort study was conducted in a 900-bed tertiary-level teaching hospital. The adult (ICU), where approximately 2000 patients are admitted yearly, is a 26-bed closed mixed medical-surgical unit with intensivists present 24 hours per day, 7 days a week. During the study period, daily sedation interruption, daily assessment of readiness to extubate, semirecumbent positioning, and

chlorhexidine-based oral care were standard procedures in the treatment of invasively ventilated patients [22-25]. In addition, selective digestive decontamination and nasotracheal intubation were avoided. Patients were mainly intubated via orotracheal route with low-pressure high-volume cuffed endotracheal tubes with an internal diameter of 7 to 8 mm. However, the nasal route was the most frequently used route for enteral feeding. The reporting of this study complies with the Strengthening the Reporting of Observational Studies in Epidemiology Statement.

Data collection and outcomes

All invasively ventilated (≥ 48 hours) adult (≥ 18 years) patients referred for head CT/MRI from October 2014 to June 2015 were eligible for enrolment and monitored daily until ICU discharge or death. Patients were excluded if they had human immunodeficiency virus infection or significant immune suppression defined as prolonged neutropenia (> 1 week) or long-term steroid therapy at a dosage ≥ 40 mg of prednisolone daily for a duration of > 4 weeks. In addition, patients with facial, orbital, or skull fractures were excluded.

The data was collected from the medical records, computerized laboratory system, and the picture archiving and communication system. *Demographic and clinical* data including age, gender, and admission diagnosis were collected from medical database. In addition, the highest and lowest temperatures and white blood cell counts were measured daily until ICU discharge or death. Acute Physiology and Chronic Health Evaluation (APACHE II), the new Simplified Acute Physiologic Score (SAPS II), and Sequential Organ Failure Assessment (SOFA) scores were recorded at the time of ICU admission [26-28]. Clinical outcomes including the duration of mechanical ventilation, the length of ICU and hospital stay, and mortality rates were recorded.

The radiographic findings of paranasal sinus changes were evaluated by a radiologist and otorhinolaryngologist together, who were blinded to clinical data and did not participate in the treatment of the study patients (consensus was found together in case of disagreement). Patients were scanned with CT only for clinical purposes. When the CT scan of the head did not cover the maxillary sinuses, one extra image slice from the middle of the maxillary sinuses was obtained using axial scanning mode. Two CT scanners were used: Toshiba Aquilion One (Toshiba Medical Systems, Tokyo, Japan) and Siemens Sensation 64 (Siemens Healthcare, Erlangen, Germany). All images of a head were scanned using 120 kV tube voltage and helical scanning mode. The average radiation dose for head scans was CT Dose Index 48.6 mGy, Dose Length Product (DLP) 788 mGy*cm, and for one extra image slice 18.5 mGy, DLP 7.8 mGy*cm.

Both sides of maxillary, sphenoid, ethmoid, and frontal sinuses were graded separately according to the Lund-Kennedy (L-K) radiologic staging with modest modifications: grade 0 (normal, ≤ 3 mm mucosal thickening at any point in the sinus), grade 1 (minor change, ≥ 4 mm mucosal thickening at any point in the sinus), or grade 2 (major change, air-fluid level, gas bubbles, or total opacification) yielding a total score range from 0 to 16

points [29-30]. In addition, the spreading of paranasal changes into maxillary, sphenoid, ethmoid, and frontal sinuses was evaluated using a score range from 0 to 4 describing how many sinus groups were involved.

According to Agrafiotis et al. [9], radiographic VAS (R-VAS) was defined as the presence of complete opacification or an air fluid level (L-K grade 2) in maxillary sinuses in CT (or MRI) in a patient on mechanical ventilation for > 48 hours. Centers for Disease Control and Prevention criteria were used to assess the presence or absence of opacities compatible with pneumonia [31].

Data analysis

A data base was created using Microsoft Office Excel 2007 (Microsoft, Redmond WA, USA) and the statistical analyses were performed with the use of SPSS 22.0 for Windows (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Demographic and clinical data were presented using frequencies and percentages for categorical data and medians and 25th-75th percentiles for continuous data. Categorical variables were analysed using the χ^2 test. The Mann-Whitney *U* test was applied for comparison of continuous variables. *P* value < 0.05 was considered significant.

Ethics

This study was approved by the relevant academic centre, and it was reviewed by the local *ethics committee* during the autumn of 2014. Written informed consent from participants or their relatives was obtained prior to inclusion in the study (Declaration of Helsinki 2013).

Results

A total of 85 patients' charts were reviewed. Three patients were excluded due to previous sinus surgery and four patients due to facial, orbital, or skull fractures. In addition, 19 patients had no radiological images available for the analysis. A total of 59 patients were included in the final analysis (Figure 1). Most of them were neurosurgical (53.3%) male (66.1%) patients with an average age of 59 (45.0-67.0) years. All of included patients were orotracheally intubated meanwhile 93.3% of patients had nasogastric tube. At admission, the median APACHE score was 20.0 (14.0-25.0), the median SAPS II score was 47.0 (34.0-57.0), and the median SOFA score was 8.0 (6.0-10.0). The median duration of mechanical ventilation was 6.9 (4.5-14.4) days, the median ICU and hospital lengths of stay were 9.6 (5.9-15.9) and 19.0 (12.0-31.0) days, respectively, and mortality rate was 25.4%.

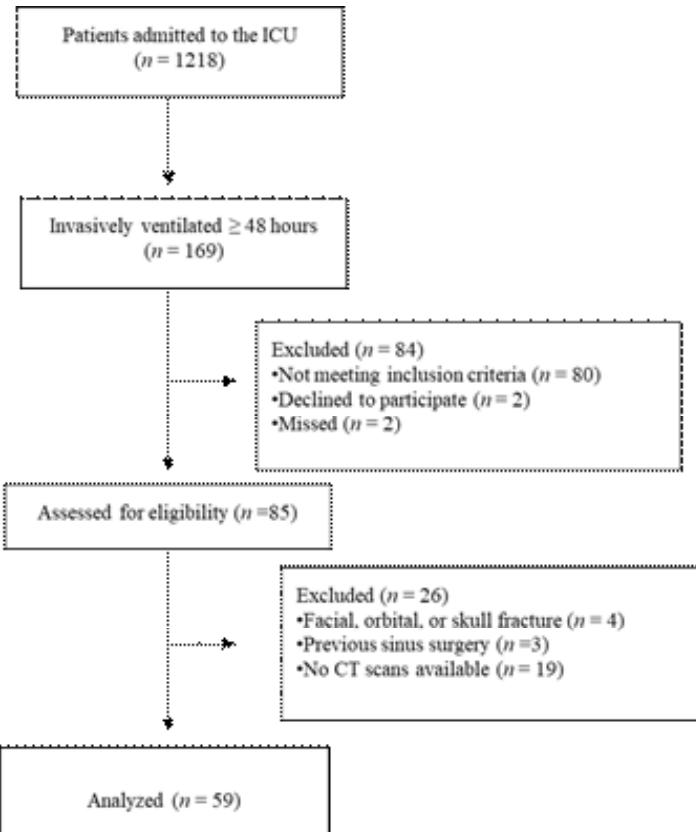


Figure 1: Flow chart of included patients.

Occurrence of paranasal changes

During the study period altogether 167 (95.4%) sinus CT and 8 (4.6%) MRI scans (median number of imaging tests, 2.0 [1.0-4.0]) were performed. Twenty-six (15.6%) CT scans did not extend above maxillary sinuses. In addition, in two patients the frontal sinuses had not developed. In general, 6.8% (5.7 per 1,000 patient days) of patients had major findings in their maxillary (R-VAS), 22.0% (18.5 per 1,000 patient days) in sphenoidal, 6.8% (5.7 per 1,000 patient days) in ethmoidal, and 3.4% (2.9 per 1,000 patient days) in frontal sinuses, respectively (Table 1). Overall, paranasal changes spread averagely into 2.0 (1.0-3.0) sinuses (Table 2), and the median L-K score was 3.0 (1.0-5.0) out of 16 points (Table 3). The presence of an *air-fluid* level was observed in 39.0%, 35.6%, and 8.6% of maxillary, sphenoidal, and frontal sinuses, respectively. Fifty-five percent of paranasal changes occurred on the day of ICU admission.

Characteristics	No changes (n=11)	Major changes in maxillary sinuses (n=4)	Major changes in sphenoidal sinuses (n=13)	Major changes in ethmoidal sinuses (n=4)	Major changes in frontal sinuses (n=2) ^a	P value ^b
Age (years)	67.0 (47.0-76.0)	56.5 (31.3-57.8)	58.0 (47.5-70.0)	57.0 (47.0-64.8)	68.5 (Na)	0.66
Gender (male)	5 (45.5)	3 (75.0)	5 (8) (61.5)	4 (100.0)	1.0 (50.0)	0.58 ^c
Admission diagnosis						0.61 ^b
Surgical	3 (27.3)	0.0 (0.0)	1 (7.7)	1 (25.0)	1.0 (50.0)	
Neurosurgical	5 (45.5)	2 (50.0)	10 (76.9)	1 (25.0)	1.0 (50.0)	
Medical	3 (27.3)	2 (50.0)	2 (15.4)	2 (50.0)	0.0 (0.0)	
APACHE II ^d	26.0 (17.0-28.0)	22.0 (14.5-24.3)	9.0 (6.5-10.5)	21.0 (12.5-24.3)	22.5 (Na)	0.96
SAPS II ^d	50.0 (41.0-65.0)	55.0 (33.0-66.5)	51.0 (47.5-62.0)	55.5 (37.0-66.5)	60.5 (Na)	0.07
SOFA ^d	10.0 (8.0-12.0)	10.0 (7.8-10.8)	9.0 (6.5-10.5)	9.5 (7.5-10.8)	9.5 (Na)	
L-K score	0.0 (0.0)	8.5 (3.5-12.0)	7.0 (4.5-8.5)	11.0 (10.0-12.0)	8.5 (Na)	<0.001*
Spreading (sinuses)	0.0 (0.0)	0.5 (0.0-3.3)	2.0 (1.5-3.0)	4.0 (1.0-4.0)	2.5 (Na)	0.08
MV (days)	5.5 (4.4-11.5)	11.7 (4.6-16.2)	13.6 (63.4-16.1)	8.8 (5.9-14.7)	9.6 (Na)	0.51
ICU LOS (days)	7.4 (5.2-9.6)	11.9 (5.8-16.6)	14.9 (9.9-16.9)	9.5 (6.4-15.4)	12.7 (Na)	0.78
VAP (yes)	2 (18.2)	0.0 (0.0)	3.0 (23.1)	0.0 (0.0)	1.0 (50.0)	>0.9 ^c
28-day mortality (yes)	5 (45.5)	1 (25.0)	1 (7.7)	1 (25.0)	1.0 (50.0)	0.21 ^c

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; MV, mechanical ventilation; Na, Not Available; L-K, Lund-Kennedy; SAPS II, the new Simplified Acute Physiology Score; SOFA, Sequential Organ Failure Assessment; VAP, Ventilator-associated pneumonia.

^a 75th percentile not available due to limited sample size.

^b P value < 0.05 was considered significant.

^c Pearson's chi-squared test

^c Fisher's exact test

^d At admission

Table 1: Clinical characteristics and outcomes of the patients with and without major changes in paranasal sinuses.

Characteristics	0 sinus group (n=19)	1 sinus group (n=8)	2 sinus groups (n=13)	3 sinus groups (n=12)	4 sinus groups (n=7)	P value
Age (years)	56.0 (50.0-70.0)	60.5 (39.5-67.0)	61.0 (42.0-70.0)	60.0 (42.0-66.0)	61.0 (44.0-67.0)	>0.9
Gender (male)	10 (52.6)	5 (62.5)	9 (9.2)	10 (83.3)	5 (71.4)	0.51 ^b
Admission diagnosis						0.67 ^b
Surgical	3 (15.8)	2 (25.9)	3 (23.1)	2 (16.7)	2 (28.6)	
Neurosurgical	12 (3.2)	6 (75.0)	6 (46.2)	5 (41.7)	3 (42.9)	
Medical	4 (21.1)	0.0 (0.0)	4 (30.8)	5 (41.7)	2 (28.6)	
APACHE II ^a	20.0 (14.0-26.0)	19.5 (10.8-21.8)	17.0 (12.5-23.5)	20.5 (15.3-25.3)	20.0 (13.0-29.0)	0.76
SAPS II ^a	50.0 (37.0-65.0)	43.0 (31.0-51.8)	44.0 (33.5-53.5)	48.5 (34.8-62.09)	52.0 (32.0-66.0)	0.71
SOFA ^a	9.0 (7.0-11.0)	9.0 (7.0-10.0)	7.0 (4.5-8.5)	9.0 (6.0-10.8)	9.0 (7.0-11.0)	0.47
L-K score	0.0 (0.0)	1.5 (1.0-4.5)	3.0 (3.0-5.0)	6.0 (5.0-7.0)	10.0 (7.0-10.0)	<0.001*
MV (days)	5.9 (4.4-9.2)	9.0 (4.9-16.9)	9.4 (4.5-18.2)	7.3 (4.3-12.9)	7.9 (5.3-16.3)	0.7
ICU LOS (days)	7.0 (5.5-9.6)	15.7 (8.6-20.6)	14.1 (6.8-21.1)	9.7 (6.7-14.3)	11.1 (5.9-16.8)	0.21
VAP (yes)	3 (15.8)	3 (37.5)	2 (15.4)	3 (25.0)	1 (14.3)	0.70 ^b
28-day mortality (yes)	7 (36.8)	1 (12.5)	4 (30.8)	2 (16.7)	1 (14.3)	0.53 ^b

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; MV, mechanical ventilation; L-K, Lund-Kennedy; SAPS II, the new Simplified Acute Physiology Score; SOFA, Sequential Organ Failure Assessment; VAP, Ventilator-associated pneumonia.

* P value < 0.05 was considered significant.

^a At admission

^b Pearson's chi-squared test

Table 2: Clinical characteristics and outcomes of the patients with and without paranasal sinus spreading.

	Lund-Kennedy 0 points (n=10)	Lund-Kennedy 1-8 points (n=43)	Lund-Kennedy >8 points (n=6)	P value
Age (years)	68.5 (53.8-77.3)	59.0 (41.0-66.0)	62.5 (53.0-73.3)	0.07
Gender (male)	4 (40.0)	31 (72.1)	4 (66.7)	0.16 ^b
Admission diagnosis				0.85 ^b
Surgical	3 (30.0)	8 (18.6)	1 (16.7)	
Neurosurgical	4 (40.0)	25 (58.1)	3 (50.0)	

Medical	3 (30.0)	10 (23.2)	2 (33.3)	
APACHE II ^a	26.0 (18.5-28.0)	19.0 (13.0-22.0)	23.5 (17.5-26.8)	0.041*
SAPS II ^a	53.5 (44.8-65.3)	44.0 (31.0-52.0)	60.5 (47.0-66.8)	0.022*
SOFA ^a	10.0 (7.8-12.3)	8.0 (5.0-10.0)	9.0 (7.0-10.3)	0.08
Spreading (sinuses)	0.0 (0.0)	2.0 (1.0-3.0)	4.0 (1.5-4.0)	<0.001*
MV (days)	5.2 (4.2-7.6)	7.9 (4.3-15.7)	7.8 (5.2-11.4)	0.41
ICU LOS (days)	6.6 (5.1-9.5)	11.5 (6.5-17.1)	8.9 (5.7-12.5)	0.12
VAP (yes)	1 (10.0)	11 (25.6)	0.0 (0.0)	0.23 ^b
28-day mortality (yes)	5 (50.0)	8 (18.6)	2 (33.3)	0.11 ^b

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; ICU, intensive care unit; MV, mechanical ventilation; SAPS II, the new Simplified Acute Physiology Score; SOFA, Sequential Organ Failure Assessment; VAP, Ventilator-associated pneumonia.

* P value < 0.05 was considered significant.

^a At admission

^b Pearson's chi-squared test

Table 3: Clinical characteristics and outcomes of the patients with and without minor and major abnormalities.

Spreading of paranasal sinus changes

In the first imaging (median day of first imaging, 0 [0.0-4.0]), 42.6% of patients had minor findings in their maxillary, 41.7% in sphenoidal, 50.0% in ethmoidal, and 17.2% in frontal sinuses. Of the findings in maxillary, sphenoidal, ethmoidal, and frontal sinuses, 0.0%, 8.3%, 3.3%, and 3.4% were major, respectively. The presence of an *air-fluid* level was observed in 24.1%, 18.3%, and 5.3% of maxillary, sphenoidal, and frontal sinuses, respectively.

Thirty-nine out of 59 patients (66.1%) were imaged twice (median day of 2nd imaging, 3 [1.0-7.0]). In the second imaging, 59.4% of them had minor findings in their maxillary, 48.7% in sphenoidal, 56.4% in ethmoidal, and 29.7% in frontal sinuses. Of the findings in maxillary, sphenoidal, ethmoidal, and frontal sinuses, 2.7%, 12.8%, 5.1%, and 0.0% were major (R-VAS), respectively. The presence of an *air-fluid* level was observed in 24.3%, 24.3%, and 8.3% of maxillary, sphenoidal and frontal sinuses, respectively.

Twenty-seven out of 59 patients (45.8%) were imaged on three occasions (median day of third imaging, 6 [4.5-12.0]). In the third imaging, 61.9% of them had minor findings in their maxillary, 59.3% in sphenoidal, 51.9% in ethmoidal, and 26.9% in frontal sinuses. Of the findings in maxillary, sphenoidal, ethmoidal, and frontal sinuses, 4.8%, 18.5%, 7.4%, and 0.0% were major, respectively. The presence of an *air-fluid* level was observed in 38.1%, 34.6%, and 12.0% of maxillary, sphenoidal and frontal sinuses, respectively.

Association between paranasal changes and ICU-related outcomes

Of the 59 patients included in the analysis, 20.3% (28.5 per 1,000 patient days) developed VAP. In these patients, 0% of

patients had major findings in their maxillary, 23.1% in sphenoidal, 0.0% in ethmoidal, and 50.0% in frontal sinuses, respectively. The total score of L-K (6.0 [2.0-7.0] vs. 4.0 [1.0-6.0]) (Figure 2) or the spreading of paranasal change (1.5 [0.25-3.0] vs. 2.0 [0.0-3.0]) (Figure 3) did not differ between patients with and without VAP. Overall, the incidence of VAP, mortality and resource utilization did not differ between patients with and without paranasal sinus changes. VAP was, however, associated with younger age (47.5 [23.5-59.5] vs. 64.0 [47.0-68.0], *p* = 0.006) and excess length of ventilator (12.8 [6.5-18.3] vs. 5.9 [4.3-11.3], *p* = 0.026) and ICU (15.7 [12.2-19.4] vs. 9.2 [5.8-14.1], *p* = 0.009) days.

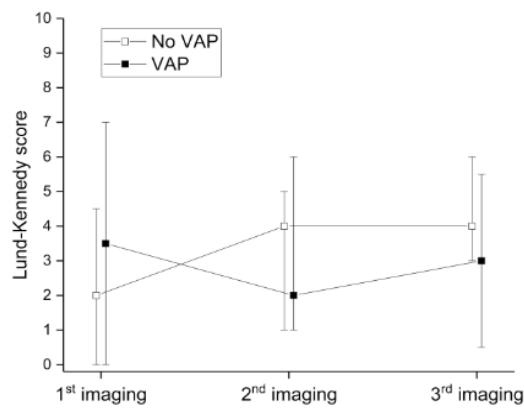


Figure 2: During the repeated computed tomography scans, the total Lund-Kennedy score increased from 2.0 out of 16 points (0.0-5.0) in the first imaging to 4.0 out of 16 points (2.0-6.0) in the third imaging.

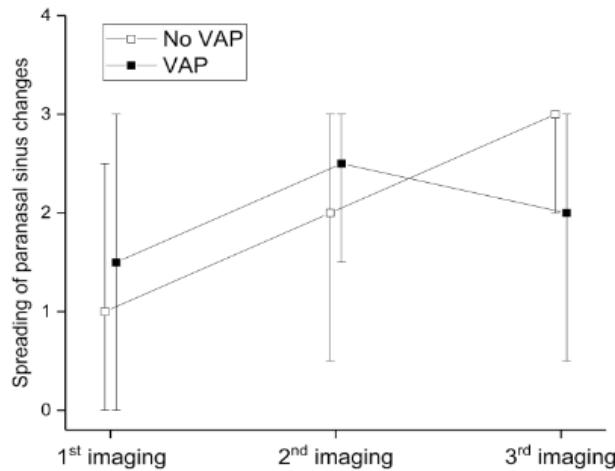


Figure 3: During the repeated computed tomography scans, paranasal sinus changes spread averagely from 1.5 sinuses (0.0-3.0) in the first imaging to 3 sinuses (1.0-3.0) in the third imaging.

Discussion

In our study, 20.3% of patients developed VAP, while 6.8% developed R-VAS. The spreading of paranasal sinus changes doubled in time. In addition, radiographically proved accumulation of fluid within the sinuses affected more than one-third of intubated patients. However, the incidence of VAP, mortality and resource utilization did not differ between patients with and without paranasal sinus changes.

In the literature [9], VAP has been present in 41% of patients with clinical VAS (C-VAS). In addition, the average frequency of C-VAS in patients with R-VAS has been 51-57%. Meanwhile selective digestive tract decontamination, bridled feeding tubes, daily sedation interruption and a physician-driven sedation protocol have been associated with a lower incidence of C-VAS. In this study, the incidence of VAP did not differ between patients with and without paranasal sinus changes.

In previous literature, the incidence of R-VAS has varied between 7.7% and 82.7% among critically ill patients [4-9]. Discrepancies between the studies may be due to differences in the definition of sinusitis, patient populations, inclusion criteria, and preferred route of tracheal and gastric intubation. In previous literature, the frequency of R-VAS has been higher in nasotracheally intubated and fed patients than in orotracheally intubated patients [9]. In our population, everyone was orotracheally intubated.

In concordance with previous literature [9], almost half of the patients had minor findings in one or both maxillary sinuses in the first imaging. In addition, the spreading of paranasal sinus changes doubled in time. In previous literature, the spreading of paranasal sinus changes has been evaluated only among children

[32] and healthy adult volunteers [33]. With the exception of patients with VAP, the resource utilization did not differ between patients with and without paranasal sinus changes. In line with previous literature, paranasal sinus changes were not associated with excess mortality [9].

Radiographically proved accumulation of fluid within the sinuses affected more than one-third of intubated patients. Meanwhile, in the literature, it has affected more than half of intubated patients [9]. According to a recent meta-analysis, radiographic evidence of accumulation of fluid within sinuses, but without a confirmed infection, is more likely in patients with nasotracheal/gastric intubation. On the other hand, other risk factors, such as anatomic variations and patient position, should be taken into account.

In the study by Agrafiotis et al. [9], the same pathogen was isolated from blood and culture specimens of sinuses in 20% of patients. In this study, however, paranasal sinus changes were detected without sinus aspiration. Without microbiological assurance we cannot rule out the possibility that the cause of paranasal sinus changes shown in the established imaging findings may have been other than infection. However, direct examination of sinus aspirates may be false negative in patients receiving antibiotics [5,12].

In diagnosing, CT scanning is one of the most important diagnostic methods. Imaging bias in this study was minimized by training of the radiologist and the otorhinolaryngologist in the use of the L-K scoring system. Despite the above-mentioned limitations, the findings of this study offer some valuable clinical insights.

In conclusion, paranasal sinus changes were common and progressive among critically ill patients undergoing invasive ventilation, without unfavourable impact on ICU-related outcomes. This study, however, has several limitations. The fact that this was a single-center study with a limited sample size may limit the generalizability of the obtained results. In addition, study population were predominantly male and relatively young neurosurgical patients. Therefore, the results may not be transferable to dissimilar populations. Secondly, we could not correlate CT/MRI findings with clinical symptoms because all the included patients were intubated and sedated and thus unable to communicate symptoms. In the previous literature, however, the correlation between CT findings and clinical symptoms has been weak [33], and fever has been a common symptom among ICU and neurosurgical patients. In addition, the occurrence of paranasal sinus changes prior to the first imaging and after discharge is unknown.

Ethical considerations

This study was approved by the relevant academic centre, and it was reviewed by the local ethics committee during the autumn of 2014. Written informed consent from participants or their relatives was obtained prior to inclusion in the study (Declaration of Helsinki 2013).

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