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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

The influence of atmospheric pressure on aortic aneurysm rupture — is the diameter of the aneurysm important?

Tomasz Urbanek, Maciej Juśko, Alfred Niewiem, Wacław Kuczmik, Damian Ziaja, Krzysztof Ziaja

Department of General and Vascular Surgery, Medical University of Silesia, Katowice, Poland

Abstract

Background: The rate of aortic aneurysm rupture correlates with the aneurysm's diameter, and a higher rate of rupture is observed in patients with larger aneurysms. According to the literature, contradictory results concerning the relationship between atmospheric pressure and aneurysm size have been reported.

Aim: In this paper, we assessed the influence of changes in atmospheric pressure on abdominal aneurysm ruptures in relationship to the aneurysm's size.

Methods: The records of 223 patients with ruptured abdominal aneurysms were evaluated. All of the patients had been admitted to the department in the period 1997–2007 from the Silesia region. The atmospheric pressures on the day of the rupture and on the days both before the rupture and between the rupture events were compared. The size of the aneurysm was also considered in the analysis.

Results: There were no statistically significant differences in pressure between the days of rupture and the remainder of the days within an analysed period. The highest frequency of the admission of patients with a ruptured aortic aneurysm was observed during periods of winter and spring, when the highest mean values of atmospheric pressure were observed; however, this observation was not statistically confirmed. A statistically non-significant trend towards the higher rupture of large aneurysms (> 7 cm) was observed in the cases where the pressure increased between the day before the rupture and the day of the rupture. This trend was particularly pronounced in patients suffering from hypertension ($p = 0.1$).

Conclusions: The results of this study do not support the hypothesis that there is a direct link between atmospheric pressure values and abdominal aortic aneurysm ruptures.

Key words: abdominal aortic aneurysm, atmospheric pressure, aneurysm rupture

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INTRODUCTION

Abdominal aortic aneurysm rupture (AAAR) is one of the major issues in both vascular surgery and vascular disease-related mortality [1, 2]. The primary reason for the continued high mortality in AAAR patients is that many of these patients are unaware of the presence of this illness. The presence of an abdominal aortic aneurysm (AAA) is often asymptomatic, and its rupture, which is often experienced as abdominal pain or a backache, can be misdiagnosed by both the patient and medical staff, particularly if no previous knowledge of the disease has been reported [2]. According to clinical observations, the risk of an AAAR significantly increases with an increase in the aneurysm's diameter [1]. Among the other factors that potentially can be related to the rupture of an aortic aneurysm, uncontrolled arterial hypertension, smoking and increased age should be considered [1, 2]. In recent years, many studies on the aetiology of AAA and on AAAR's pathogenic factors have been performed [3, 4]. In addition to the research performed in the fields of pathology and molecular biology, investigations have been conducted focusing on other factors that are potentially related to aneurysm ruptures. One interesting possible factor in this regard is the influence of weather conditions, primarily the influence of the atmospheric pressure on the potential for an aneurysm rupture [5–7]. Despite the important

Address for correspondence:
Tomasz Urbanek, MD, PhD, Department of General and Vascular Surgery, Medical University of Silesia, ul. Ziołowa 45/47, 40–635 Katowice, Poland,
e-mail: urbanek.tom@interia.pl
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role of the AAA's diameter itself, an aneurysm rupture may also occur either in cases of small aneurysms or in areas that do not necessarily have the largest diameter. This finding suggests the presence of areas of lowered resistance of the aneurysm wall, and in this case it is important to consider other factors that may potentially promote a rupture incident, such as the current blood pressure or, at least hypothetically, the atmospheric pressure surrounding the patient [8].

Conflicting results are found in the available literature concerning the influence of atmospheric pressure on aneurysm rupture [5–7, 9–13]. The relatively small sizes of the evaluated populations and the lack of an analysis of the aneurysms' sizes did not allow determination of the influence of the atmospheric pressure on the AAA ruptures. Assuming that the risk of rupture increases with the aneurysm's diameter, the possible influence of external factors may affect patients who have an initially increased risk of rupture in different ways. To determine the potential role of one of these external factors, we assessed in this study the influence of changes in atmospheric pressure on abdominal aneurysm ruptures in relation to the aneurysm size.

METHODS

Study population

The clinical records of 223 subjects with ruptured AAAR in the Department of General and Vascular Surgery, Medical University of Silesia in Katowice, between 1997 and 2007 were retrospectively analysed. This group contained 29 (13%) women and 193 (87%) men. The mean age was 70 ± 9.05 years for the men and 75 ± 10.21 years for the women. According to the imaging study data (ultrasound or computed tomography angiography), all of the admitted subjects were diagnosed with a rupture of an abdominal aortic aneurysm. The diameter of the aneurysms at the time of rupture ranged from 40 mm to 160 mm, with a mean of 82 mm (mean size 83 mm in the men [40–160 mm] and 75 mm [40–110 mm] in the women). The patients' concomitant diseases were also evaluated — according to the clinical record analysis, in 135 (59.6%) patients coronary heart disease was reported. In 122 (54.7%) patients arterial hypertension and in 22 (9.8%) patients diabetes was noted.

According to the analysis of the medical records, the day of the AAAR was identified in all cases. The medical data relating to the aneurysm's rupture were compared with the environmental data (atmospheric pressure) obtained from the Regional Inspectorate of Environmental Protection in Katowice in Silesia, Poland.

Atmospheric pressure

In the analysis, the average daily atmospheric pressure in the period from 1997 to 2007 was considered, and the pressure on the days of aneurysm ruptures were compared with the pressure on the days when there were no subjects hospitalised related to an AAAR incident. All of the subjects were inhabitants of the same area of the Silesian region (population size ca. 2 million), for which our department was the emergency referral vascular surgery centre during this period. In addition to the differences in the pressure between the days with and without AAAR admissions, the seasonal pressure differences were evaluated, as were the pressure differences between the day before the rupture and the day of the rupture. In the analysis the aneurysm's size was also considered; the subjects were divided into five groups to evaluate the results in regard to the aneurysms' diameters (Table 1).

Table 1. Aneurysm size in the study cohort

Diameter of ruptured aneurysm	Number of patients (%)
< 55 mm	18 (8%)
55–69 mm	36 (15.9%)
70–84 mm	69 (31.3%)
85–99 mm	45 (20.2%)
> 100 mm	55 (24.5%)

Statistical analysis

For the statistical analysis, STATISTICA 10.0 StatSoft software was used, and ANOVA, χ^2, and Student's t-tests were conducted. A level of significance $p < 0.05$ was considered statistically significant.

RESULTS

In the evaluated material, when the days with a reported AAAR and the days without rupture were compared, no significant differences in the average daily atmospheric pressure were observed ($p > 0.05$) (Fig. 1). This applies both to the entire population and each of the subgroups according to the diameter throughout the analysis period.

Similar observations of the average daily atmospheric pressures in the days directly preceding ruptures were also made, and there were no statistically significant differences between the pressure on this day and the remainder of the days in the period (Fig. 1).

An analysis of the mean monthly atmospheric pressure and the number of patients hospitalised in particular months and seasons of the year revealed a non-statistically significant tendency toward more frequent AAAR admissions during the winter and spring months (Fig. 2), when the higher average pressures were observed (Fig. 1).

To evaluate the possible influence of rapid changes in atmospheric pressure, the average daily atmospheric pressure between the day of the rupture and the day preceding the rupture were also compared. In this analysis, we did not find statistically significant differences either in the overall group or in the subgroups specified according to the aneurysm diameter

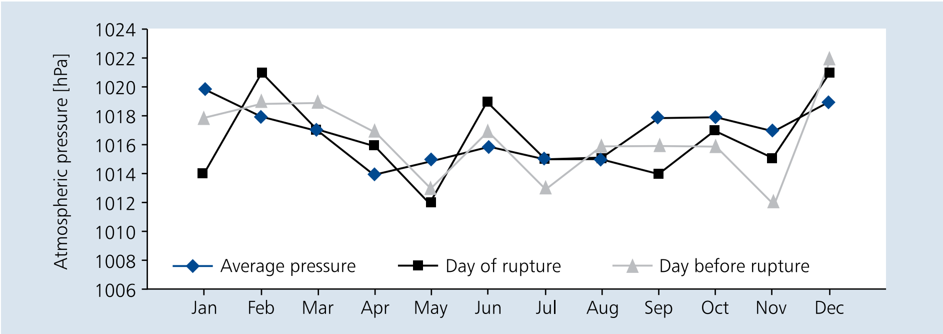

Figure 1. Average atmospheric pressures on the days of rupture, the days before rupture, and in the whole analysed period in the years 1997–2007 (from January to December)

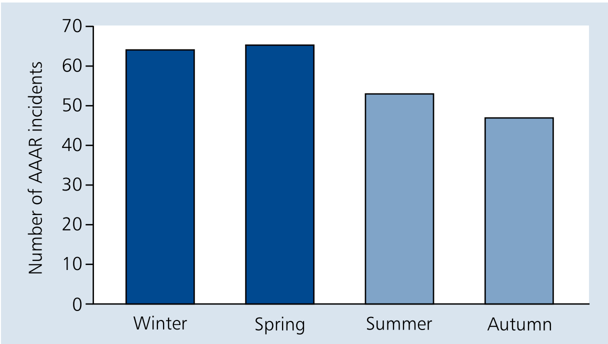

Figure 2. Number of abdominal aortic aneurysm rupture (AAAR) admissions in relationship to the season of the year

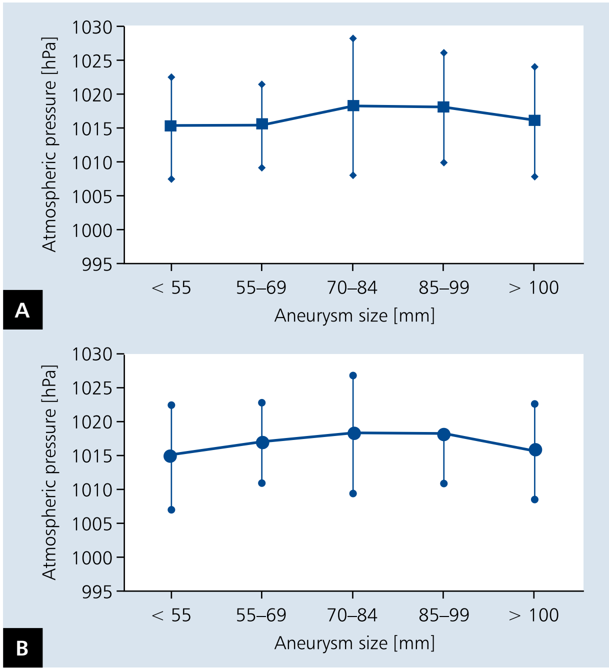

Figure 3. Average atmospheric pressure (± maximum and minimum average pressure value) on the days of rupture (**A**) and the days preceding rupture (**B**)

(Fig. 3A, B). The only significant difference documented was the higher daily average atmospheric pressures on the day of the rupture and on the preceding day that were observed in the group with an aneurysm diameter from 70 mm to 84 mm compared with the other groups selected according to aneurysm size ($p < 0.05$). However, there were also no statistically significant average pressure differences between the day before and the day of rupture in this group (Fig. 3A, B).

When seeking a potential influence of a trend toward an increase or decrease in the pressure between the day before and the day of the rupture, an interesting observation was made (Fig. 4A, B). In patients with aneurysms of a larger size, AAARs occurred more frequently when the pressure increased. This trend was particularly pronounced in the patients suffering from hypertension ($p = 0.1$; ANOVA) (Fig. 4A). In the group with aneurysms of a smaller size, we were unable to document similar findings.

DISCUSSION

In the literature of the last several decades, many studies have been published analysing the various potential factors related to acute vascular incidents such as AAAR or the rupture of cerebral artery aneurysms [2]. Despite studies based on molecular biology and on pathology and physiology methods, the direct mechanism of these ruptures remains unknown. The description based on Laplace's law (the direct correlation between the pressure inside a cylindrical object and its diameter) explains the tendency for the higher aneurysm rupture rate in the group with larger aneurysms. However, ruptures also occur in smaller aneurysms. To explain this observation, a precise analysis of aneurysm wall changes and the influence of other potential factors should be undertaken. In the literature, both the qualitative and quantitative changes in collagen and in the elastin fibres, as well as their structures in the aortic wall, have been described [14]. The role of smooth muscle cell apoptosis, intra- and periaortic inflammatory reaction, and the disturbance of the aortic wall's feeding vessels have been investigated [15, 16]. According to the studies performed, the

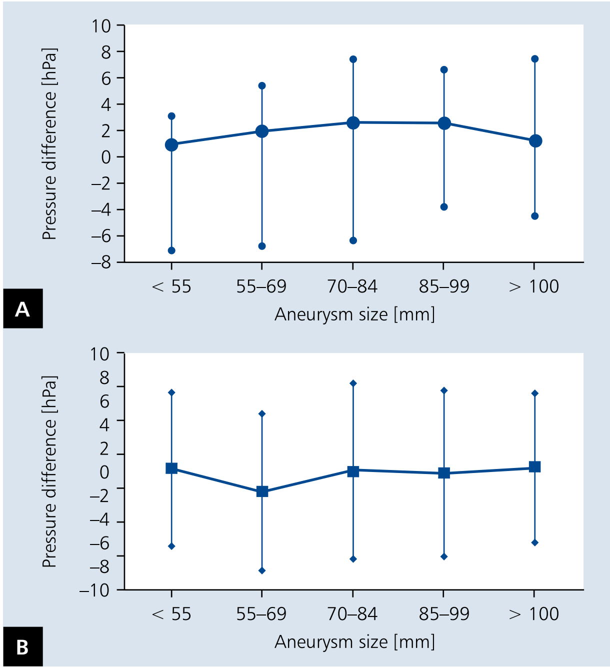

Figure 4. Pressure differences between the day before the rupture and the day of abdominal aortic aneurysm rupture in the group of patients with abdominal aortic aneurysm rupture with (**A**) and without (**B**) arterial hypertension — the evaluation in relationship to the aneurysm size

role of the aneurysm sac thrombus and the intramural activity of the metalloproteinases and their inhibitors should also be investigated [14, 15]. In the search for both clinical and potentially modified factors, uncontrolled arterial hypertension and smoking have been suggested to affect the growth of an aneurysm [17]. As documented in imaging- and autopsy-based studies, aortic aneurysm blisters with reduced resistance can be observed in some cases; however, in the intraoperative and the autopsy reports, it continues to be difficult to definitively confirm the location of the rupture in the suspected places only [18]. Despite the potentially higher risk of rupture in these areas, a rupture of the aortic aneurysm occurs outside this region in many cases. This observation indicates the need for further research into the potential factors influencing the risk of an aneurysm rupture (other than the commonly used diameter of an aneurysm). In this field, research on the role of environmental factors must be discussed, although various and often contradictory results are presented in the available literature.

At least theoretically, the pressure gradient between the aortic lumen and extra-vascular space is determined not only by the arterial blood pressure but also by the atmospheric pressure that surrounds the patient. It has been suggested that episodes of lower atmospheric pressure are related to the most frequent aneurysm ruptures; however, recently-published papers dispute this idea [10–13]. In 2003, Bown et al. [19] described a correlation between a lower average daily atmospheric pressure in the months preceding the incidents of AAAR and the risk of AAAR. However, they were unable to document a significant difference between the average daily atmospheric pressure on the days of AAAR incidents and other days in the analysed period. An interesting conclusion was the observation of more frequent AAARs during the winter and spring months (peaking in March) and less frequent AAARs in summer and autumn (especially in July) [19]. A correlation between the seasonal differences in the number of patients admitted because of AAAR and the differences in the atmospheric pressure was also confirmed in our study, with a higher rate of ruptures in the winter and spring months, when higher average pressures were observed. Other authors have also suggested that both the season of the year and the atmospheric pressure influence the frequency of AAARs. Hakin et al. [20] observed that the variations in the frequency of AAARs were dependent on the season of the year and on periods of lower atmospheric pressure (particularly in patients with non-regulated arterial hypertension). Indications of the influence of low atmospheric pressure on more frequent AAARs can be found in the study of Smith et al. [9], which was based on a retrospective analysis of 182 cases of AAAR in the United Kingdom. The authors discovered that on the days of rupture incidents there was a lower daily average atmospheric pressure compared with the days on which patients were not hospitalised. A logistic regression analysis revealed a correlation between low atmospheric pressure and the frequency of AAARs. Additionally, AAAR incidents occurred more often during periods with higher average pressure variations [9]. It should be emphasised that the observations described above have not been confirmed by other researchers. Robert et al. [10] investigated the presumptive correlation between AAARs and atmospheric pressure, based on material from 19 district hospitals in France in the period 2005–2009. A similar analysis was conducted using the cause of death database in France for the same period. These data were correlated with the atmospheric pressure values. The authors investigated a total of 494 AAAR cases reported from 19 hospitals and 6358 cases from the national database. The number of ruptured aneurysms and the number of deaths related to AAAR changed in relation to the season of the year, but both of these numbers peaked in winter (January). This observation correlated with the significantly higher atmospheric pressure values in the winter months. Additionally, a positive correlation between the atmospheric pressure and AAARs was reported, particularly in regard to the maximum average daily atmospheric pressure in the months before the incidents [10]. Moreover, other investigators have not confirmed the potential role of low atmospheric pressure in the rupture of aneurysms [11]. In 2014, Kózka et al. [11] retrospectively analysed 530 subjects with AAAR over a 10-year observation period in regard to weather events, atmospheric pressure, temperature, and humidity. There was no confirmed correlation between the AAARs and the atmospheric pressure. Similar observations were found in the paper by Schuld et al. [12], who analysed 191 subjects with AAAR in the period 1994–2011. This research did not reveal a significant correlation between the average atmospheric pressure on the days of incidents and the days when incidents did not occur. Simultaneously, according to that analysis, the authors suggested that changes in the atmospheric pressure within the four days preceding the rupture had potentially influenced a higher AAA rupture frequency. According to the analysis of the autopsy protocols of the two main Rome hospitals in 2013, Sterpetti et al. [21] identified 77 cases of AAAR (among a total of 49,144 dissection autopsy reports). After comparing these data with the weather conditions, no correlation between the AAARs and atmospheric pressure was detected, but a significant influence of the temperature changes was observed. The lack of a confirmed relationship between atmospheric pressure and aneurysm ruptures was also described by Molacek et al. [22] in an analysis based on 54 ruptured aneurysm cases, and in a paper by Kurtoglou et al. [23] based on 24 cases. Contradictory results were described in two other papers. Killeen et al. [24] reported a higher frequency of ruptures on days with a higher average atmospheric pressure (an observation based on a cohort of 107 patients). Kordzadeh et al. [13], according to a study based on 50 AAAR reports, suggested a higher risk of rupture in periods of lower atmospheric pressure. Those authors evaluated the size of the aneurysm, but found no differences related to the diameter of the aneurysm. In light of the often very contradictory results, an interesting paper from Japan by Takagi et al. [25] should be considered. The authors analysed the data from 150 AAARs in an eight-year observation period and performed a meta-analysis of the eight studies (including their own data). Both the data from their own centre and the meta-analysis suggested that there was a lower average atmospheric pressure on the days when ruptures occurred (in contrast to the remainder of the year). The results of our study did not confirm this conclusion for either the small or large ruptured aortic aneurysms. Additionally, as suggested by some of the previously mentioned authors (that were not submitted to the analysis performed by the group of Takagi), a higher admission rate of AAAR patients was observed in the winter and spring months, when a higher mean atmospheric pressure is typically observed [25]. We also did not confirm an influence of the changes in atmospheric pressure between the day before a rupture and the day of the rupture in our data. Considering the potential coincidence of various factors influencing the risk of an aneurysm rupture (which were generally not assessed in the previous studies), an important conclusion of the analysis accounts for the changes in atmospheric pressure, the presence of arterial hypertension, and the size of the aneurysm. In our study, in the group of patients suffering from arterial hypertension with larger aneurysms, an increase in the atmospheric pressure (in comparison with the previous days) resulted in a trend toward a higher rate of aneurysm rupture. This finding may suggest the potential relationship between atmospheric pressure changes and aneurysm ruptures if additional risk factors are also present (arterial hypertension and a large aneurysm). Of course, we are unable to compare the patients' arterial pressures at the moment of aneurysm rupture. However, considering this observation, further studies of the influence of atmospheric pressure on the risk of aneurysm ruptures are needed. Simultaneously, the potential influence of weather changes on patients' health and their current arterial pressure should be investigated (both of which are potentially related to the atmospheric conditions, weather changes, and abnormalities).

CONCLUSIONS

The results of the study do not support the hypothesis that there is a direct link between atmospheric pressure values and abdominal aortic aneurysm ruptures.

Conflict of interest: *none declared*

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Wpływ ciśnienia atmosferycznego na ryzyko pęknięcia tętniaka aorty brzusznej — czy średnica tętniaka ma znaczenie?

Tomasz Urbanek, Maciej Juśko, Alfred Niewiem, Wacław Kuczmik, Damian Ziaja, Krzysztof Ziaja

Katedra i Klinika Chirurgii Ogólnej i Naczyń, Śląski Uniwersytet Medyczny, Katowice

Streszczenie

Wstęp: Ryzyko pęknięcia tętniaka aorty brzusznej koreluje ze wzrostem średnicy tętniaka aorty. Wśród różnych czynników wpływających na wzrost ryzyka pęknięcia wymienia się w szczególności nadciśnienie tętnicze, niewiele wiadomo natomiast o innych potencjalnych czynnikach związanych z wystąpieniem tego powikłania. Zgodnie z doniesieniami z piśmiennictwa istnieją sprzeczne dane odnoszące się do wpływu ciśnienia atmosferycznego na ryzyko pęknięcia tętniaka aorty.

Cel: Celem pracy było określenie związku między zmianami ciśnienia atmosferycznego a ryzykiem pęknięcia tętniaka aorty brzusznej, z uwzględnieniem aktualnej średnicy tętniaka.

Metody: W pracy przeanalizowano materiał dotyczący 223 chorych z pękniętym tętniakiem aorty brzusznej hospitalizowanych w Klinice Chirurgii Ogólnej i Naczyń w latach 1997–2007 (chorzy hospitalizowani w poszczególnych latach zamieszkiwali ten sam region kraju). Analizie poddano średnie dzienne ciśnienia atmosferyczne w dniach, w których zanotowano pęknięcia, a także w dniach poprzedzających pęknięcie i w dniach kolejnych. Wyniki analizowano z uwzględnieniem średnicy pękniętego tętniaka aorty u hospitalizowanych chorych.

Wyniki: Nie stwierdzono istotnej statystycznie różnicy między średnim ciśnieniem atmosferycznym w dniach, w których hospitalizowano pacjentów z pękniętym tętniakiem aorty brzusznej oraz w pozostałych dniach w analizowanym okresie. Największą częstość hospitalizacji chorych z pękniętym tętniakiem aorty brzusznej zanotowano w okresie zimy i wiosny, kiedy równocześnie obserwowano wyższe średnie wartości ciśnienia tętniczego — obserwacje te nie okazały się jednak istotne statystycznie. W grupie chorych z tętniakiem aorty brzusznej o średnicy powyżej 7 cm stwierdzono nieistotny statystycznie trend w kierunku większej częstości hospitalizacji z powodu pękniętego tętniaka aorty brzusznej w przypadku wzrostu wartości ciśnienia między dniem poprzedzającym pęknięcie a dniem pęknięcia. Powyższy trend był szczególnie zaznaczony w grupie pacjentów z tętniakiem i nadciśnieniem tętniczym w wywiadzie ($p = 0{,}1$)

Wniosek: Wyniki niniejszego badania nie potwierdzają hipotezy sugerującej bezpośredni związek wartości ciśnienia atmosferycznego i jego zmian z ryzykiem pęknięcia tętniaka aorty brzusznej.

Słowa kluczowe: tętniak aorty brzusznej, ciśnienie atmosferyczne, pęknięcie tętniaka

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Adres do korespondencji:
dr hab. n. med. Tomasz Urbanek, Katedra i Klinika Chirurgii Ogólnej i Naczyń, Samodzielny Publiczny Szpital Kliniczny nr 7, Śląski Uniwersytet Medyczny, ul. Ziołowa 45/47, 40–635 Katowice, e-mail: urbanek.tom@interia.pl
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