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ORIGINAL ARTICLE

Thoracotomy and decortication: impact of culture-positive empyema on the outcome of surgery

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Abstract

OBJECTIVES: This study aimed to assess the efficacy of thoracotomy and decortication (T/D) in achieving lung re-expansion in patients with Stage III empyema and assess the impact of culture-positive empyema on the outcome of decortication.

METHODS: This is a retrospective observational study of consecutive patients treated with T/D over a 6-year period.

RESULTS: A total of 107 consecutive patients were identified. The median age was 55 (range 16–86) years; of which, 86% were male. The median length of hospital stay was 9 (range 2–45) days. Full lung re-expansion was achieved in 86% of cases. There were no postoperative deaths. Pleural cultures were positive in 56 (52%) cases. Patients with culture-positive empyema had a longer duration of pleural drainage (median of 11 days, range 3–112 versus median of 5 days, range 3–29 days for negative culture; $P = 0.0004$), longer length of hospital stay (median of 11 days, range 4–45 versus median of 7 days, range 2–34 days; $P = 0.0002$) and more complications ($P = 0.0008$), respectively. There was no statistically significant difference in the outcome of surgery, i.e. lung re-expansion versus trapped lung ($P = 0.08$) between the two groups.

CONCLUSIONS: T/D is safe and achieved lung re-expansion in the majority of patients. Culture-positive empyema was associated with worse outcomes.

Keywords: Thoracotomy and decortication • Stage III empyema • Bacterial culture

INTRODUCTION

Pleural empyema, defined as the accumulation of pus in the pleural cavity, occurs most commonly in association with community-acquired pneumonia (parapneumonic effusions) [1]. While many small parapneumonic effusions will resolve without surgical intervention, ~10% will become loculated or progress to empyema [2]. The American Thoracic Society describes the three phases of empyema as exudative (Stage I), fibrinopurulent (Stage II) and organizing (Stage III). In the initial exudative stage, closed chest drainage and appropriate antibiotic administration can comprise effective treatment. The development of loculations and/or a visceral pleural cortex in a persisting effusion (Stage II) may render antibiotic treatment and tube drainage alone ineffective at controlling symptoms of sepsis or achieving full lung re-expansion. Minimally invasive video-assisted thoracic surgery (VATS) techniques can achieve pleural cavity clearance and lung re-expansion in this stage of empyema through pulmonary surface debridement and breakdown of loculations [3, 4]. An established fibrothorax characteristic of a Stage III empyema usually requires a thoracotomy and full visceral pleural decortication to re-expand the entrapped lung and eradicate the pleural infection [5, 6]. We hypothesized that empyema with positive pleural bacterial culture was associated with worse outcomes after thoracotomy and decortication (T/D).

The aim of this study was to assess the impact of culture-positive empyema on the outcome of decortication (rate of lung re-expansion, reintervention, length of hospital stay and duration of pleural drainage), and to describe the patterns of microbiological causes of empyema.

MATERIALS AND METHODS

This is a retrospective observational study of 107 consecutive patients with community-acquired pleural empyema who underwent T/D over a 6-year period in our department. Patients were excluded if they had co-existing pleural malignancy or hospital-acquired post-surgical empyemas. Ethical approval for this study

was obtained from the institutional review board (IRB number 3410). Patients were divided into two groups based on whether samples taken at surgery grew micro-organisms (positive pleural cultures) or did not (negative pleural cultures).

Surgical protocol

All patients had a full preoperative assessment including a full blood count, coagulation screen and renal and liver function testing. In addition, all patients had a chest radiograph and chest CT scan. The decision to operate was based on CT scan evidence of a pleural cortex (fibrothorax) with or without a residual pleural collection and symptoms consistent with an empyema. T/D was performed as a primary procedure in patients with an established fibrothorax without any previous thoracic intervention. A proportion of patients had already undergone a previous surgical intervention but, despite this, had still developed an established fibrothorax and these had T/D as a secondary procedure.

All operations were performed under general anaesthesia with single-lung ventilation as tolerated. The patient was placed in a lateral decubitus position, and the chest cavity was accessed through a posterolateral thoracotomy. A limited rib resection was performed, if required, to facilitate entry into the pleural cavity. Extrapleural stripping was performed by blunt dissection to mobilize the corticated part of the lung and the thickened parietal pleural cortex incised. The pleural cavity was evacuated of all fluid and debris, samples of which were sent for microbiological staining and culture.

Decortication was undertaken by complete resection of the visceral cortex over the entire lung surface including the fissures, until full lung re-expansion was achieved. The pleural cavity was lavaged with 2–3 l of warm saline or water and dilute povidone-iodine (10%). The pleural cavity was drained with one or more large-bore (28 or 32 Fr) chest drains. Suction was applied to these drains at 20 cmH_2O.

Patients were extubated in the theatre if well enough prior to transfer to the recovery room. Pleural drains were kept in until there was full lung expansion, no active parenchymal air leak and full evacuation of the pleural fluid (usually 3–5 days). A small number of patients, who developed prolonged air leaks (longer than 7 days) but who were otherwise well, were discharged with a drain attached to a bag with a flutter valve and followed up in the weekly pleural disease clinic until the drains could be removed.

Criteria for a successful operation included radiographic evidence of full lung re-expansion and the absence of residual pleural collection or pleural thickening after drain removal when compared with preoperative radiological imaging. Treatment failure was defined as incomplete lung re-expansion on discharge or after drain removal, with or without a residual effusion or pleural thickening with persistent lung entrapment. Patients requiring reoperation were also classified as treatment failures.

Patients were followed up in the thoracic surgical outpatients' clinic at 1 month and discharged back to their referring physician or primary care physician once a full recovery was apparent.

Microbiology

Prospective computerized microbiological records of all patients were reviewed, and the following data were obtained: microbiological specimens (i.e. perioperative pleural debris samples) and blood culture samples.

The standard treatment pathway depends on the severity of the specific patient's condition. If possible, antibiotics are withheld until surgical samples can be obtained to optimize organism identification and tailor antimicrobial treatment. However, some patients were inter-hospital transfers from District hospitals to our thoracic unit and they had been commenced on antibiotics prior to arrival. In these cases, the antibiotic regime was continued until appropriate culture and sensitivity results were available. Antibiotics were commenced postoperatively, and in our hospital co-amoxiclav would be the antibiotic of choice unless previous microbiological results indicated an appropriate alternative. Treatment was altered based on microbiological results and continued for 2 weeks postoperatively. This was extended in some cases depending on patient progress and microbiological results.

Radiology

Postoperative lung expansion was assessed with chest radiography (CXR). All CXRs were reviewed and reported by a radiologist who was blinded to the study. Full lung re-expansion was defined as a fully inflated lung from diaphragm to apex with no lucency or blunting of costophrenic or cardiophrenic angles on at least two postoperative CXRs, one of which was taken after pleural drain removal. The presence of costophrenic, and/or cardiophrenic, blunting with a fluid meniscus on CXR after removal of pleural drains was defined as a residual effusion. The presence of pleural thickening with failure of full lung re-expansion (a residual space) on CXR was reported as residual pleural cortex. Chest CT scans were performed in cases of failure of full lung re-expansion or residual effusion with clinical signs of persisting infection, and radiologically guided drainage was performed as required.

Data collection

Individual patient data were obtained from a prospective surgical database and patient case notes. Microbiological data were likewise obtained from a prospectively collected database. Radiological imaging was reviewed from archived images.

Statistical analysis

Continuous data are reported with medians and ranges, and categorical data with counts and percentages. Survival was measured from the date of surgery. Univariate analysis of data was performed using the χ^2 test, log-rank test, Fischer's exact test, unpaired *t*-test and analysis of variance, where appropriate. A *P*-value of <0.05 was considered statistically significant. All analyses were conducted using the SPSS software package (version 18, SPSS, Inc.).

RESULTS

Patients characteristics

Between January 2007 and December 2012, 117 patients had a T/D for empyema. Ten patients with iatrogenic or hospital-acquired empyemas were excluded from the study (cardiac surgery $n = 6$;

oesophagectomy $n = 2$; splenectomy with perisplenic abscess $n = 1$ and lobectomy for lung cancer $n = 1$). The remaining 107 patients were enrolled in this study. All patients had radiological evidence of Stage III empyema on preoperative chest CT scans.

Eighty-one (86%) patients were male. The median age was 55 (range 16–84) years. Fifty (47%) patients had a left-sided, and 57 (53%) a right-sided operation ($P = 0.40$). Baseline characteristics are summarized in Table 1.

Smoking history did not significantly correlate with either postoperative complications or surgical outcome of full lung re-expansion after decortication ($P = 0.46$ and 0.65, respectively). Likewise, a previous history of alcoholism did not significantly correlate with postoperative complications or full lung re-expansion after decortication ($P = 0.44$ and 0.45, respectively).

Table 1: Baseline characteristics of all patients ($n = 107$)

Age, years median (range)	55 (16–84)
Gender, *n* (%)	
Male	81 (76)
Female	26 (24)
Smoking, *n* (%)	
Non-smoker	16 (15)
Smoker	16 (15)
Previous smoker	35 (33)
Unknown	40 (37)
Diabetes mellitus, *n* (%)	
No	100 (94)
Yes	7 (7)
Cardiovascular disease	
Atrial fibrillation	4
Myocardial infarction	4
Pulmonary embolism	2
Alcoholism	
No	100
Yes	7
Chest disease	
Previous pneumonia	41
Chronic obstructive pulmonary disease	7
Previous tuberculosis	6
Asthma	1
Previous haemothorax/pleural effusion	6
Previous lung resection	1
Others[a]	4
Rheumatoid arthritis	
No	105
Yes	2
Side	
Left	50 (47)
Right	57 (53)

[a]Obstructive sleep apnoea ($n = 1$) and previous chest trauma ($n = 3$).

Operative outcomes and complications

There were no in-hospital or 30-day postoperative deaths. Full lung re-expansion was achieved in 62 (58%) patients. A further 30 (28%) patients had residual lung entrapment following drain removal on CXR, but subsequently achieved full lung re-expansion at a median of 5 (range 1–8) weeks without the need for further surgical intervention. Fifteen (14%) patients had a persistent effusion requiring long-term pleural drainage. Three (2.8%) patients required reintervention after decortication, 2 of them with pleural drains and 1 with a VATS debridement. The overall failure rate was 14%. The distribution of postoperative complications between the two groups is presented in Table 2.

Patients with positive pleural cultures were more likely to have a persistent entrapment of the lung after decortication, with odds ratio (OR) of 2 (95% CI 0.6–6.5), and to have a persistent pleural effusion or pleural abscess, with OR of 4 (95% CI 1.0–14.9). These patients with positive cultures were also more likely to develop postoperative complications, with OR of 3.89 (95% CI 1.71–8.87), and to have prolonged pleural drainage longer than 7 days, with OR of 1.36 (95% CI 0.48–3.91), compared with patients with negative pleural cultures.

We analysed the duration of hospital stay in the two groups. To dichotomize this, we calculated percentiles for days in hospital postoperatively. We used the 90th percentile as a cut-off value. The 90th percentile for the length of hospital stay was 26 days. There were 9 patients with a length of hospital stay longer than 26 days, 7 of whom had a positive culture ($P = 0.09$). Patients with positive cultures were more likely to stay in hospital longer than 26 days, with OR of 3.5 (95% CI 0.71–18.07).

Clinical findings and previous pleural interventions

The distribution of previous pleural interventions and outcomes of surgery is summarized in Table 3. Thirty-two (30%) patients had a T/D as the primary treatment for their empyema (no previous pleural intervention). VATS pleural debridement had been performed in 52 (49%) patients and intercostal tube thoracostomy had

Table 2: Distribution of postoperative complications in the two groups

Complication	Negative culture, *n* (%)	Positive culture, *n* (%)
No	38 (75)	24 (43)
Prolonged air leak	6 (12)	14 (25)
Postoperative anaemia and bleeding	3 (6)	2 (4)
Trapped lung	2 (4)	5 (9)
Respiratory insufficiency	2 (4)	9 (16)
Bronchopleural fistula	0	1 (2)
Other complications	0	1 (2)

$P = 0.03$, the complication rate is higher in the positive culture group.

Table 3: Previous pleural interventions and outcome of decortications in the two groups

Variable	Negative culture, *n* (%)	Positive culture, *n* (%)
No operation	19 (37)	13 (23)
Previous chest drain	8 (16)	11 (20)
Previous thoracoscopy	24 (48)	28 (50)
Thoracotomy and decortication	0	4 (7)
Postoperative complications	13 (26)	32 (57)
Postop long-term drain	7 (14)	13 (17)
Postop trapped lung or persistent effusion	20 (39)	25 (45)

Table 4: Postoperative complication (*n* = 45)

Prolonged air leak[a]	20 (19)
Postoperative bleeding	5 (5)
Postoperative sepsis	7 (7)
Respiratory insufficiency[b]	11 (10)
Bronchopleural fistula	1 (1)
Dysphagia	1 (1)

The values are denoted as *n* (%).
[a]Prolonged air leak longer than 7 days.
[b]One case of respiratory insufficiency was related to postoperative gastrointestinal bleeding which required reoperation.

Table 5: Micro-organism in the pleural fluid

No growth	51 (48)
Streptococcus pneumoniae	18 (17)
Tuberculosis	6 (6)
Enterobacter spp.	1 (1)
MRSA	4 (4)
Staphylococcus aureus	5 (5)
Aspergillus fumigatus	1 (1)
Pseudomonas aeruginosa	7 (7)
Enterococcus spp.	9 (16)
Others[a]	5 (5)

The values are denoted as *n* (%).
[a]*Klebsiella pneumonia* (*n* = 1), *Serratia marcescens* (*n* = 1), *Haemophilus influenzae* (*n* = 1) and *Escherichia coli* (*n* = 2).

been performed in 19 (18%) patients prior to decortication. During the study period, 377 patients had a VATS pleural debridement for empyema in our institution; of which, 52 went on to subsequently require a T/D. The rate of treatment failure of VATS debridement was 14%. Only 4 (3.7%) patients had a previous T/D for empyema and subsequently had a redo operation. The median length of time between the previous treatment and the decortication was 1.3 (range 0–75) months. There was no correlation between previous operation and results of decortication ($P = 0.14$), but there is a statistical correlation between the time between the two operations and the results of decortication in the case of recurrence of empyema after the first operation ($P = 0.0001$). The majority (60.4%) of study patients who required decortication after a failed VATS procedure were reoperated on within a month. The median length of drainage was 7 (range 3–112) days.

The median length of hospital stay was 9 (range 2–45) days. Seven (6.5%) patients were transferred back to their local hospital a median of 5 days after the operation to continue antibiotic treatment. Sixteen (15%) patients were discharged home with one chest drain; the median length of hospital stay of these patients was 10 (range 6–28) days. The median duration between discharge from the hospital and drain removal for patients who went home with drains was 19 (range 4–95) days.

Forty-five (42%) patients developed postoperative complications (Table 4). Six patients developed excessive perioperative bleeding. One patient (with underlying liver dysfunction) had the chest packed and these packs were subsequently removed after 24 h. Two further patients required reoperation, and 3 others were managed conservatively. Six patients developed postoperative sepsis requiring cardiovascular support with inotropes; 2 of these required reoperation. One patient developed a bronchopleural fistula (BPF), which required a reoperation and window thoracostomy. This patient had methicillin-resistant *Staphylococcus aureus* (MRSA) empyema.

Microbiology of pleural specimens and relation to surgical outcomes

Positive microbiology with cultured organisms was obtained in 56 (52%) cases (Table 5). Ninety-five (89%) patients were treated with postoperative antibiotics, and 44 (41%) were discharged home with continuing treatment. Patients with positive pleural microbiology had a longer duration of pleural drainage (median of 11 days, range 3–112 versus median of 5 days, range 3–29 days for negative culture; $P = 0.0004$), longer hospital stay (median of 11 days, range 4–45 versus median of 7 days, range 2–34 days; $P = 0.0002$) and higher rate of complications ($P = 0.0008$), respectively. There was no statistically significant difference in the outcome of surgery, i.e. lung re-expansion versus trapped lung ($P = 0.08$) between the two groups, or number of patients discharged with a pleural drain *in situ* between the two groups ($P = 0.5$).

The median duration of antibiotic treatment was 14 (range 4–192) days. All 6 patients with tuberculosis (TB) received antimicrobial treatment for 6 months. All 12 patients who did not receive any postoperative antibiotics had normal total white cell counts and C-reactive protein (CRP) levels <5 mg/l with no other systemic signs of infection. Antibiotic treatment was stopped in patients who had no bacterial growth from pleural culture specimens sent from surgery and had no clinical signs of ongoing infection on advice of the infectious disease team.

Twenty-three (22%) patients had at least one episode of postoperative pyrexia (T > 38°C), and all these patients had blood cultures taken, of which only one was positive, with MRSA isolated. The median preoperative CRP level was 71 mg/l (range 5–415; normal range <5), and the median white blood cell count (WCC) was 10 000/ml (range 3800/ml–30 800/ml; normal range 4000/ml–11 000/ml). A raised CRP and WCC above the normal range were not related to postoperative complications ($P = 0.6$ and 0.4, respectively) and with the postoperative outcome ($P = 0.9$ and 0.5).

In a subgroup analysis, positive microbiology with Gram-negative organisms cultured from pleural fluid samples sent at surgery significantly correlated with the development of any complication after surgery ($P = 0.002$), but there was no correlation with any one specific complication. The presence of positive pleural cultures from the time of surgery did not appear to influence the efficacy of decortication ($P = 0.08$).

The underlying pathogen did appear to affect the surgical outcome: mycobacterial, pseudomonal and MRSA pleural space infections were associated with a higher rate of adverse outcomes (failure of lung re-expansion and postoperative complications) compared with *Streptococcus pneumoniae* and other Gram-positive infections ($P = 0.03$). Persistent lung entrapment was seen in 4 of 6 TB patients, 2 of 4 patients with MRSA and 5 of 7 patients with pseudomonal empyemas.

DISCUSSION

In this study, we demonstrate that T/D achieves full lung re-expansion in over half of patients at a median of 9 days after surgery and >85% of cases within 1 month after surgery, with no postoperative in-hospital deaths. Patients with culture-positive empyema had worse outcomes compared with those with no active bacterial infection. Organization of a parapneumonic pleural effusion produces a dense, avascular collagen matrix that walls off the insulting fluid [7]. Complete resection of this dense pleural cortex by T/D facilitates re-expansion of the entrapped lung. Although several studies have reported on favourable outcomes of T/D for chronic empyema with most patients 'cured', it is not clear which criteria they used to make this assertion [8–10]. We systematically reviewed postoperative archived chest imaging to assess for full re-expansion of the lung, comparing these CXRs with preoperative radiographs. Any evidence of residual pleural fluid or rind with or without lung entrapment was classified as incomplete lung re-expansion. It is important to note that failure to completely re-expand the lung and obliterate the pleural space after decortication leaves the potential for fluid re-accumulation, postoperative empyema, persistent dyspnoea and restriction to chest wall mechanics [7, 11].

From our study, it is clear that patients with ongoing bacterial pleural infection that yielded positive bacterial cultures had significant postoperative morbidity even after decortication was performed to eradicate the pleural infection and re-expand their lung. These patients had a longer duration of pleural drainage and longer length of hospital stay, were more likely to develop postoperative complications and had a higher rate of treatment failure characterized by persistent pleural effusion/abscess or trapped lung.

In these patients, eradication of the bacterial pleural infection with a prolonged course of antibiotics and continued drainage is subsequently achieved in most of the cases. This, however, often requires a long-term pleural drain, further surgery to resect the empyema cavity or rib resection with creation of a window thoracostomy. We recommend a multidisciplinary approach to management of these patients with liaison of the surgical team with infectious disease specialists and family physicians to facilitate management of long-term drainage and prolonged intravenous antibiotics in the community.

Proponents of minimally invasive (VATS) techniques for surgical decortication claim that there is a shorter duration of pleural drainage and hospital stay and less postoperative complications and pain with a mortality and morbidity benefit, compared with T/D [11–14]. However, VATS pleural 'decortication' in these studies has mainly been employed for Stage II empyema in which an organized pleural cortex has not yet formed [11–13]. Moreover, lung re-expansion was not achieved in as many as 41% of VATS cases of 'pleural debridement' [14]: these patients subsequently required a T/D. In addition, the median hospital length of stay for patients with VATS decortication for organized empyema was 18.5–21 days, with a mortality rate between 5.6 and 6.6% [13, 14]. Our study only included patients with Stage III empyema with organized effusions and a fully developed pleural cortex. The median hospital stay in our cohort was 9 days with no postoperative mortality.

In cases of Stage II empyema, VATS pleural debridement is effective in achieving infection control and lung re-expansion [15]. The empyema stage is an important determinant of success of VATS debridement [14]. The failure rate of VATS debridement during the duration of our study was 14% with these patients going on to develop a pleural cortex and undergoing a T/D. There was no statistically significant difference in outcomes between patients with previous VATS debridement and primary T/D. We therefore believe that patients with a fully developed pleural cortex with lung entrapment should have a T/D as the procedure of choice unless unfit for this type of surgery.

Although the complication rate in our series was relatively high, the majority of cases were patients with persistent air leaks i.e. longer than 7 days. Although troublesome, air leaks usually resolve promptly once full lung re-expansion is achieved [7]. Patients discharged home with pleural drains in our series had their drains removed a median of just under 3 weeks after discharge from the hospital after their air leaks stopped. None of these patients required any further intervention.

The distribution of bacterial causes of empyema in our series was similar to previously published series with the exception of a lower percentage of staphylococcal species [12, 16]. In our study, perioperative cultures isolated organisms in just under half of the cases. Culture negativity may reflect prior antibiotic exposure. As noted by Marks *et al.* [12] who reported similar results in a large series, this highlights the necessity for the development of more sensitive diagnostic tests for detection of microbiological causes of empyema. Mandal *et al.* [8] reported that aerobic Gram-negative bacilli such as *Pseudomonas* and *Klebsiella* in the pleural space elicit an acute inflammation associated with systemic toxicity that does not allow adequate time for a polymorphonuclear cell response that precedes a monocyte-mediated fibroblast proliferation over the pleura. This fibroblast proliferation is necessary for the formation of a pleural cortex to wall off the insulting bacterial infection. The absence of this mature pleural cortex makes surgery difficult with significant bleeding as the plane of dissection between the cortex and visceral pleura is ill-defined [8, 17]. This can result in significant air leaks, BPFs and persistent pleural infection. We found that infection with *Pseudomonas* was more likely to result in incomplete lung expansion after decortication.

Patients with culture-positive empyema in our study suffered more postoperative morbidity with longer duration of pleural drainage, longer length of hospital stay and a higher rate of complications. Although not statistically significant, there was a trend towards better lung re-expansion rates in patients with negative pleural cultures. The clinical significance of lung re-expansion in empyema cannot be overemphasized. Elimination of the empyema cavity, re-expansion of the lung and removal of all infected debris are all important in eradicating infection in these patients [18]. Patients with positive pleural cultures would usually have a prolonged course of intravenous antibiotics (at least 2 weeks) with at least one pleural drain left *in situ*. They would have repeated cultures of drain fluid until sterile. This would explain the longer duration of pleural drainage and hospital stay.

Consistent with published epidemiology, we show that empyema is predominantly a male disease [12, 18]. The risks of trauma and higher rates of alcoholism associated with the male gender may explain the susceptibility to staphylococcal, Gram-negative, anaerobic and mycobacterial infections, all of which we identified as causative organisms for empyema [12].

The limitations of this study mainly relate to the retrospective design with its inherent selection bias. In addition, assessment of fitness for surgery in itself selects against patients with significant comorbidity, advanced age and general ill-health in whom poor outcomes from any treatment would be expected. We were unable to match patients in the two groups for other risk factors for empyema, such as previous malignancy, chemotherapy and immunosuppresive illness, as these numbers were very small and the data were unreliable owing to the fact that many of the patients were sent to us as in-patient transfers from general hospitals and we did not have access to their previous medical records. Nonetheless, we believe that this large series highlights the continued efficacy of T/D in treating Stage III empyema with good results and an excellent safety profile.

In conclusion, our study demonstrates that patients with culture-positive empyema had a longer duration of pleural drainage, hospital stay and a higher complication rate than those with no active bacterial pleural infection. T/D remains the treatment of choice for Stage III empyema with good rates of lung re-expansion, a relatively short length of hospital stay and no deaths in a large cohort of patients. Furthermore, although positive pleural bacterial cultures did not adversely affect the outcome of surgery, pseudomonal, MRSA and TB pleural infections are more likely to result in incomplete lung re-expansion after decortication.

Conflicts of interest: none declared.

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