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Multidisciplinary treatment of deep neck infection associated with descending necrotizing mediastinitis: a single-centre experience

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Abstract

Objective: Deep neck infection (DNI) associated with descending necrotizing mediastinitis (DNM) is a highly lethal condition. This retrospective review was performed to share our experience performing multidisciplinary management of DNI associated with DNM during a 7-year period.

Methods: We reviewed 16 patients who had been surgically treated for DNM at Peking Union Medical College Hospital from April 2010 to July 2017. The clinical outcomes were analysed to determine the most appropriate therapeutic strategy.

Results: Five women and 11 men were included in this study. Their mean age was 54.9 ± 14.3 years. DNM-associated infections most commonly occurred secondary to odontogenic infections ($n = 10$). Thirteen patients required tracheotomy because of tracheal compression. All patients underwent unilateral or bilateral cervicotomy. Six patients with DNM localized in the upper mediastinal space underwent transcervical mediastinal drainage, while 10 patients with DNM extending to the lower mediastinum were treated by cervicotomy and video-assisted thoracoscopic surgery. Three patients died of multiple organ failure.

Conclusion: Multidisciplinary treatment can achieve favourable outcomes in >80% of patients with DNM. Early diagnosis, proper airway management, and adequate surgical drainage are crucial for reducing mortality in patients with DNM, and minimally invasive procedures also play an important role.

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Introduction

Deep neck infection (DNI) of dental and oropharyngeal origin refers to abscess formation or cellulitis in the potential spaces and fascial planes of the neck. Treatment of DNI includes airway management, prompt surgical drainage, and antibiotic therapy. If untreated or not properly treated, the downward spread of DNI can cause descending necrotizing mediastinitis (DNM), a potentially lethal form of mediastinitis.[1–3]

The diagnostic criteria of DNM were initially defined by Estrera et al.[4] in 1983 and subsequently refined by Wheatley et al.[5] in 1990. Endo et al.[6] classified DNM according to the anatomic extent: type I refers to an infection above the carina (localized form), and type II refers to an infection below the tracheal bifurcation (diffuse form). Type II is further subdivided into type IIA (lower anterior mediastinum) and type IIB (lower posterior mediastinum).

The progress in modern antibiotic treatment, advances in diagnostic and surgical techniques, and improvements in anaesthesia and intensive care protocols have resulted in a significant decrease in the mortality rates of DNI and DNM.[3,7] However, the optimal management protocol, including the best mediastinal drainage and surgical approach, is still controversial, and no guidelines have been developed to date.[2] The present study was performed to provide a reference for appropriate therapeutic intervention strategies by reviewing our experience in the treatment of patients with DNI associated with DNM during a 7-year period with a focus on the application of multidisciplinary treatment and minimally invasive procedures.

Methods

All experimental procedures were performed in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). This retrospective study was approved by the Ethics Committee of the Peking Union Medical College. All patients participating in the study provided written or verbal informed consent. The medical data of all patients presenting with DNI associated with DNM and treated at Peking Union Medical College Hospital from April 2010 to July 2017 were retrospectively collected. Most patients were referred from emergency rooms, and the diagnoses of DNI and DNM were confirmed based on the clinical findings and cervicothoracic computed tomography (CT) scans. The relationship between cervical infection and DNM was clearly established, and all patients were treated by surgical drainage and debridement.

Following establishment of the definitive diagnosis, empirical broad-spectrum intravenous antibiotics were administered, and consultation among a multidisciplinary team (including an oral and maxillofacial surgeon, an infectious disease physician, an intensive care specialist, an anaesthesiologist, a radiologist, an otolaryngologist, and a thoracic surgeon) was carried out to evaluate the need for airway management

and identify the most appropriate surgical treatment.

The surgical management, which consisted of combined cervical and mediastinal drainage, was performed by a team comprising an oral and maxillofacial surgeon, an otolaryngologist, and a thoracic surgeon. The abscess and necrotic tissue were collected intraoperatively from the deep neck and mediastinal areas and sent for bacterial cultures. The antibiotics were adjusted according to the sensitivity test results once the causative pathogen had been identified.

All patients were admitted to the intensive care unit for close monitoring and fluid and electrolyte resuscitation. Follow-up CT was performed in the surgical intensive care unit at 48 to 72 hours after the primary surgery to assess the adequacy of therapy. Re-intervention was considered necessary if a residual abscess, necrotic tissue, or unsatisfactory drainage was detected. Depending on the extent of the abscess, a repeat operation or catheter interventional therapy was performed. Once the infection had been controlled and circulatory and respiratory support was no longer necessary, the patient was transferred from the intensive care unit to the oral and maxillofacial ward.

All clinical charts, imaging findings, and bacteriological analyses were reviewed.

Results

Demographic data

During the 7-year study period, 16 patients (11 men, 5 women) diagnosed with DNM-associated DNI were treated at our hospital. Their ages ranged from 28 to 79 years (mean, 54.9 ± 14.3 years). Eight patients (50%) were given intravenous antibiotics, two patients (12.5%) received oral antibiotics prior to hospitalization, five patients (31.3%) had been hospitalized elsewhere, and three (18.8%) patients had received cervical drainage and were referred to our hospital for further management following disease progression. The delay between the onset of symptoms of the primary infection and admission to our institution ranged from 2 to 10 days (mean, 4.7 days; median, 6 days). The patients' characteristics, symptoms, comorbidities, bacteriological features, treatment course, and outcomes are shown in Table 1.

Associated comorbidities

Of the 16 patients, 10 (62.5%) presented with relevant associated systemic conditions including diabetes mellitus ($n = 8$), cardiovascular disease ($n = 5$), liver cirrhosis ($n = 1$), rheumatic disease ($n = 1$), chronic renal insufficiency ($n = 1$), Meniere's disease ($n = 1$), and bronchitis ($n = 1$). Additionally, alcohol and nicotine abuse were reported by three and seven patients, respectively.

Source of infection

The DNM-associated infections most commonly occurred secondary to odontogenic infections ($n = 10$), particularly in the second or third mandibular molars. Oropharyngeal infections, including peritonsillar abscesses ($n = 5$) and epiglottitis ($n = 1$), acted as the source in the remaining six patients.

Diagnosis

CT imaging showed signs of DNI and extension of the infection inferiorly into the mediastinum in all patients. Typical cervicothoracic CT images exhibiting mainly an anterior mediastinal collection are shown in Figure 1, and DNI with mainly a posterior mediastinal collection is shown in Figure 2. The preoperative chest CT scans showed bilateral cervical infections in nine patients, pleural effusion in three patients (bilateral in two), and pericardial effusion in one patient.

Table 1. Characteristics, treatment course, and outcome of patients with DNM.

Age (y)/ sex	Source of infection	Endo class	Main symptoms	Systemic diseases	Bacteriology	Primary surgical treatment	Tracheotomy	Plus reoperation or/and catheter interventional therapy	Complications	Outcome
57/M	Odontogenic abscess	I	Neck swelling, dyspnoea	HTN, rheumatic arthritis, Meniere's disease	None	Cervicotomy + transcervical mediastinal drainage	Y	None	Zoster facialis	Discharged after 20 days
79/M	Peritonsillar abscess	I	Dyspnoea, cough	DM, arrhythmia, bronchitis	*Streptococcus constellatus*, *Staphylococcus aureus*	Cervicotomy + transcervical mediastinal drainage	Y	VATS	Pneumonia, acute respiratory distress syndrome, septic shock, multiple organ failure	Died after 10 days
60/F	Peritonsillar abscess	I	Sore throat, dysphagia	DM	*Streptococcus anginosus*, *Peptostreptococcus*	Cervicotomy + transcervical mediastinal drainage	N	None	None	Discharged after 17 days
55/M	Odontogenic abscess	I	Neck swelling, dyspnoea	None	*Staphylococcus aureus*	Cervicotomy + transcervical mediastinal drainage	Y	None	None	Discharged after 12 days
39/M	Odontogenic abscess	I	Neck swelling, dysphagia	None	None	Cervicotomy + transcervical mediastinal drainage	N	None	Orocutaneous fistulae	Discharged after 15 days

(continued)

Table 1. Continued.

Age (y)/ sex	Source of infection	Endo class	Main symptoms	Systemic diseases	Bacteriology	Primary surgical treatment	Tracheotomy	Plus reoperation or/and catheter interventional therapy	Complications	Outcome
65/F	Epiglottitis	I	Neck swelling, thoracic pain	HTN, DM	None	Cervicotomy + transcervical mediastinal drainage	Y	Cervicotomy	Acute respiratory distress syndrome	Discharged after 23 days
49/M	Peritonsillar abscess	IIA	Neck pain	DM	*Streptococcus hemolyticus*, *Staphylococcus epidermidis*	Cervicotomy + VATS	Y	Catheter interventional therapy (1 pericardial drainage tube)	Pericardial effusion	Discharged after 20 days
63/F	Odontogenic abscess	IIA	Neck pain, thoracic pain	Liver cirrhosis	*Streptococcus anginosus Prevotella* spp.,	Cervicotomy + VATS	Y	None	Anaemia	Discharged after 17 days
42/M	Odontogenic abscess	IIA	Dyspnoea	None	*Staphylococcus aureus*	Cervicotomy + VATS	N	None	None	Discharged after 12 days
70/M	Odontogenic abscess	IIA	Neck swelling, thoracic pain	DM, HTN, CAD	None	Cervicotomy + VATS	Y	Catheter interventional therapy (1 mediastinal drainage tube and 1 mediastinal irrigation tube)	Myocardial injury	Discharged after 21 days
33/M	Odontogenic abscess	IIB	Neck swelling, thoracic pain, dysphagia, dyspnoea	None	*Streptococcus hemolyticus*, *Streptococcus viridans*, *Bacteroides* spp.	Cervicotomy + VATS	Y	2nd cervicotomy, 3rd VATS, 4th catheter interventional therapy (2 mediastinal irrigation tubes and 1 pericardial drainage tube)	Pericardial effusion, acute coronary syndrome, multiple organ failure, septic shock	Discharged after 51 days

(continued)

Table 1. Continued.

Age (y)/ sex	Source of infection	Endo class	Main symptoms	Systemic diseases	Bacteriology	Primary surgical treatment	Tracheotomy	Plus reoperation or/and catheter interventional therapy	Complications	Outcome
60/M	Peritonsillar abscess	IIB	Neck swelling, sore throat	DM, pleuritis	None	Cervicotomy + VATS + thoracotomy	Y	Catheter interventional therapy (2 mediastinal irrigation tubes and 1 pleural drainage tube)	Pulmonary embolism	Discharged after 22 days
28/M	Odontogenic abscess	IIB	Thoracic pain, dyspnoea	None	*Streptococcus viridans*	Cervicotomy + VATS	Y	Catheter interventional therapy (1 pericardial drainage tube)	Pericardial effusion	Discharged after 26 days
60/F	Odontogenic abscess	IIB	Severe facial pain and swelling	DM	*Streptococcus anginosus*, *Fusobacterium alocis*	Cervicotomy + VATS	Y	2nd VATS, 3rd cervicotomy + thoracotomy	Multiple organ failure, septic shock, acute respiratory distress syndrome	Died after 25 days
47/F	Peritonsillar abscess	IIB	Neck swelling, dysphagia	None	None	Cervicotomy + VATS	Y	None	None	Discharged after 26 days
72/M	Odontogenic abscess	IIB		DM, HTN, chronic heart failure, chronic renal insufficiency	*Streptococcus viridans*	Cervicotomy + VATS	Y	2nd cervicotomy + thoracotomy	Multiple organ failure, septic shock, acute coronary syndrome	Died after 19 days

Abbreviations: M, male; F, female; HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; VATS, video-assisted thoracoscopic surgery; Y, yes; N, no

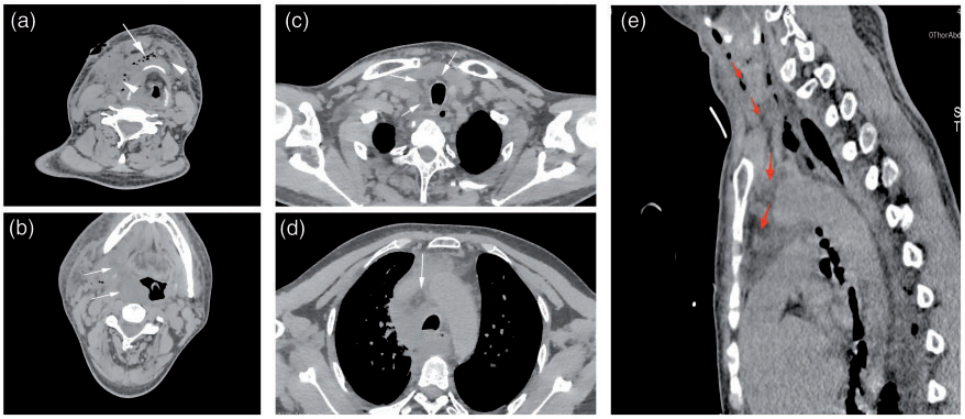

Figure 1. (a) Axial view showing gas production (arrow) and abscess formation (arrowhead) in the submental and submandibular spaces. (b) Axial view of the same collection extending into the parapharyngeal space on the right side (arrows) and airway compression. (c) The same collection spreading downward to the paratracheal space (arrows). (d) Axial view of the same collection extending into the anterior mediastinum (arrow). (e) Sagittal view of another patient showing deep neck infection with anterior mediastinal extension. The red arrows indicate the direction of infection spread.

Figure 2. (a) Axial view showing gas production (arrow) and abscess formation (arrowhead) in the prevertebral (retro-oesophageal) space. (b) Axial view of the same collection extending into the lower posterior mediastinum (oval) and bilateral thoracic empyema (arrow). (c, d) Coronal and sagittal views of the same patient showing extensive gaseous infection of the posterior mediastinum.

Therapy

Following establishment of the definitive diagnosis, antibiotic therapy was initiated empirically and modified according to the organism's specific sensitivity results. Second- and third-generation cephalosporins combined with metronidazole were most commonly used. The antibiotic treatment regimen was modified in seven patients (43.8%) based on the organism's specific sensitivity results.

Based on the CT findings, all patients underwent surgery under general anaesthesia. The interval between hospitalization and the first surgery ranged from 0 to 3 days. Surgical treatments included tracheotomy, elimination of the source of dental or oropharyngeal infection, and sufficient drainage of the neck and mediastinum. Thirteen patients required tracheotomy because of the extent of tracheal compression, and all patients underwent unilateral or bilateral cervicotomy based on the degree of spread of the infection. Cervicotomy was performed through a horizontal submandibular incision parallel to the superior border of the clavicle. The involved cervical spaces were opened, drained, and debrided of necrotic tissue. Silicone drains placed in the cervical incisions were left open for daily irrigation. The patients also underwent intraoral drainage of the abscess and extraction of infected teeth. Six patients with DNM localized in the upper mediastinal space underwent transcervical mediastinal drainage, while 10 patients with DNM extending to the lower mediastinum were treated by cervicotomy and two-port video-assisted thoracoscopic surgery (VATS). For VATS, a 1.5-cm incision was made at the level of the seventh or eighth intercostal space along the midaxillary line for the observation hole, and a 3- to 4-cm incision was made at the fourth or fifth intercostal space along the anterior axillary line for the operation hole. The procedure involved surgical debridement of the mediastinum and pleura with complete excision and decortication of necrotic tissue and adequate placement of chest tubes for drainage of the mediastinum and pleura. The abscess and necrotic tissue from the deep neck area and mediastinum were analysed for bacterial cultures.

Seven patients exhibited gradual improvement in their laboratory findings postoperatively. However, because of the highly infectious nature of DNM and the weak immunologic status of the patients, nine individuals (56.3%) required a reoperation and/or catheter interventional therapy because they exhibited unfavourable outcomes and their postoperative CT scans showed a residual abscess and necrotic tissue. Two patients required a third operation, and four patients received only catheter interventional therapy. Drainage was continued until the patient exhibited clinical progress, normal CT findings, and a negative culture of the fluids aspirated from the drainage tubes.

Bacteriology

Microbiological tests were performed in all patients, and the results showed a polymicrobial infection in six (37.5%) patients. The aerobic and anaerobic cultures from these six patients showed no growth, possibly because of prior antibiotic treatment or failed isolation of the bacteria. The most frequently observed aerobic bacteria were *Streptococcus* spp. and *Staphylococcus* spp. Mixed aerobic and anaerobic infections were observed in four patients.

Clinical outcome

The overall mortality rate was 18.75%. Three patients died of septic shock and severe, irreversible complications leading to multiple organ failure. The duration of

inpatient treatment ranged from 10 to 51 days (mean, 21.7 days; median, 20 days). Eleven patients (68.75%) exhibited complications associated with DNM, including orocutaneous fistulae (n = 1), pneumonia (n = 1), multiple organ failure (n = 4), pericardial effusion (n = 3), acute respiratory distress syndrome (n = 3), zoster facialis (n = 1), anaemia (n = 1), myocardial injury (n = 1), acute coronary syndrome (n = 2), and pulmonary embolism (n = 1). The orocutaneous fistulae were closed using a vacuum-assisted closure system, the pericardial effusion was resolved by catheter interventional therapy, and the other complications were treated using conservative medical therapy (with the exception of three patients who died of multiple organ failure).

Discussion

DNI usually presents as abscesses or cellulitis in the potential spaces and fascial planes of the neck.[7] These infections may spread to the chest and cause DNM, which is the most virulent complication of DNI and one of the most serious and often lethal forms of mediastinitis.

In the era of modern antibiotics, the mortality rate associated with DNM has fallen from between 31% and 37% reported before 1998 to 18% in the latest review.[3] However, the advanced stages of DNM are still associated with high mortality rates, particularly in developing countries with poor economic conditions and a consequent lack of medical resources for prevention and treatment of dental and oropharyngeal diseases. A delay in diagnosis plays a crucial role in these high mortality rates because DNM usually runs a fulminant course.[1,6,8,9]

The most common sources of DNI are odontogenic and pharyngeal infections. However, the widespread use of antibiotics and improvements in oral hygiene have reduced the overall incidence of the disease.[10] Moreover, odontogenic infections are becoming less common as the source of infection in DNM and have been replaced by pharyngeal infections.[2,11,12] However, the result of the current study contradicts this trend; we found that odontogenic infections were the most common source of infection leading to DNM. This could have been a result of the relatively small sample size and the fact that most of the patients included in this study were transferred from specialized stomatological hospitals.

A clear understanding of the anatomy of the cervical fascial planes is essential for successful management of DNI and DNM. Infections can spread from the deep neck spaces to the mediastinum through the retropharyngeal, vascular, and pre-tracheal spaces,[12] and the downward spread of DNI can be further accelerated by gravity, respiration, and negative intrathoracic pressure.[8,13,14] Contiguous cervicothoracic CT scans can demonstrate continuity of the infectious process from the neck to the thorax, thus establishing a relationship between neck infection and mediastinitis. This is considered to be the "gold standard" for definitive diagnosis and can also be used to direct surgical drainage and monitor the postoperative progression of DNM.[12–16] The typical CT findings of mediastinal infection include soft tissue infiltration with loss of normal fat planes, fluid collection, abscess formation, and the presence or absence of gas.

Although no guidelines or published articles have reported high-level evidence on the treatment of DNM, the need for integration of a multidisciplinary team is strongly recommended.[3] The primary treatment of DNM includes intravenous broad-spectrum antibiotics, airway management, surgical restoration of the pharyngeal or dental focus, and adequate drainage of the neck and mediastinum.[2] Septicaemia

with the possibility of toxic shock, impaired haemodynamics, and pleuropulmonary infections are frequently observed in the early postoperative stages.[13] Therefore, intensive postoperative care, simultaneous management of comorbidities, and appropriate interventional therapy also play important roles in the management of patients with DNM. The multidisciplinary team in our hospital includes an oral and maxillofacial surgeon, an otolaryngologist, a thoracic surgeon, an infectious disease physician, a radiologist, an intensive care specialist, and an anaesthesiologist (flowchart shown in Figure 3).

The need for tracheostomy in the treatment of patients with DNM is controversial. While some authors believe that tracheostomy is mandatory considering the difficulties associated with intubation, massive upper airway oedema, and the risk of aspiration,[5] others suggest that the tracheotomy site enhances contamination of the pre-tracheal space and act as a source of downward spread of infection and subsequent mediastinal involvement.[17] However, the induction of anaesthesia has made it easier to manage difficult airways using advanced airway control techniques such as the GlideScope (Verathon, Inc., Bothell, WA, USA) and fibre optic intubation. Wolfe et al.[18] suggested that tracheostomy is not routinely necessary for patients with DNI and a compromised airway. In our experience, however, compromised airways are a common symptom and DNM relapses quite easily, necessitating more than one operation and long-term treatment. Under such circumstances, early tracheotomy is recommended because it is more secure and allows the patient to be moved to a non-critical care unit at an

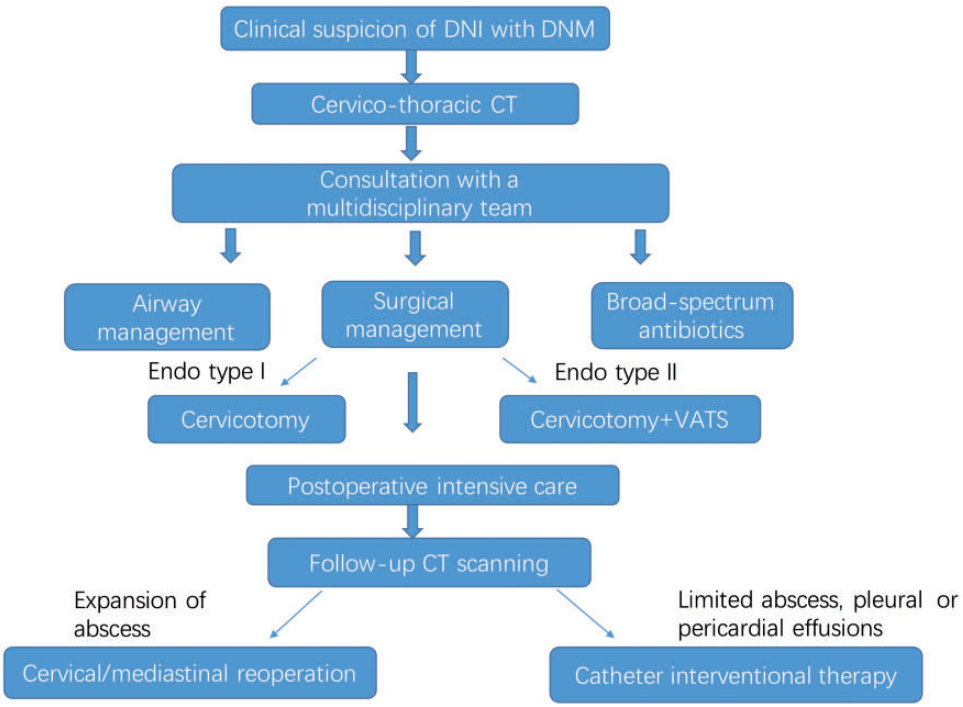

Figure 3. Management algorithm for deep neck infection with descending necrotizing mediastinitis.

earlier stage, thus reducing the overall costs.[19–21] Consistent with the reports by Ridder et al.[2] and Palma et al.,[22] no secondary infections were observed at the tracheostomy sites in the patients included in our study.

Adequate surgical drainage plays a crucial role in the treatment of DNM, and intravenous antibiotic therapy without surgical treatment is insufficient. Cervical exploration and drainage, either by unilateral or bilateral cervicotomy, is the most commonly accepted treatment measure. However, the most appropriate type of mediastinal drainage among the various approaches that have been proposed, including transcervical, subxiphoid, thoracotomy, video-assisted mediastinoscopy, and VATS, remains controversial.[1,12,16,17,23] In agreement with the majority of reports, we believe that transcervical mediastinal drainage is sufficient for DNM limited to the upper part of the mediastinum (Endo type I).[2,6,8,15,24] For drainage of the lower anterior mediastinum (Endo type IIA), several surgeons have advocated midline sternotomy or the subxiphoid approach, while posterolateral thoracotomy is generally preferred for lower posterior mediastinal involvement (Endo type IIB).[2,3,6,12] However, these aggressive approaches would worsen the situation in patients with sepsis and increase the duration of hospitalization and the risks of morbidity and mortality.[2] Based on our experience, we believe that VATS with double-lumen intubation or a blocker under tracheotomy could accomplish adequate surgical drainage and debridement for infections below the carina. This procedure can also provide better visualization of the entire thoracic cavity compared with the subxiphoid approach. VATS is also associated with significantly less access trauma and can help avoid possible complications such as osteomyelitis and dehiscence of the sternum in patients with severe DNM to a greater extent than thoracotomy. Moreover, the possibility of repeated drainage procedures makes the less invasive VATS procedure more likely to be tolerated by the patient. However, its main drawback is the need to change the operative position and the higher risk of pleural and lung contamination compared with the sternal approach. This can be treated using postoperative interventional therapy.

Some authors have suggested that percutaneous catheter drainage replaces conventional surgical drainage as the treatment of choice for cervical necrotising fasciitis and DNM.[25–27] They reported that only a small amount of necrotic tissue was removed, and the primary purpose of the surgery was opening the infected area and draining the pus. However, in agreement with several other authors, our experience showed that widespread cellulitis, necrosis, abscess formation, and sepsis extended along the planes between the deep neck fascia muscles and the mediastinum.[1,12] In such cases, aggressive surgical procedures are recommended instead of simple drainage. The importance of less invasive interventional therapy for the treatment of DNI and DNM is emphasized, but only as a supplementary tool when indicated. Postoperative interventional examinations in the present study showed that abscesses may occasionally reform, resulting in inadequate postoperative drainage, thrombosis, and formation of granulation tissue that can block the drainage tube. In such cases, new drainage and irrigation tubes should be placed. Limited pleural or pericardial effusions can also be drained using percutaneous catheter drainage. Notably, we did not use interventional therapy as the primary treatment measure, and the decision to select this minimally invasive technique was based on a multidisciplinary consultation, the patient's condition, and the extent of the disease. Therefore, our study showed that similar to the conventional approach, VATS with or without catheter interventional therapy can

achieve a low mortality rate in patients with type II DNM.[3,24]

Hyperbaric oxygen therapy is believed to have a significant survival benefit in patients with necrotizing fasciitis, limiting the extent and number of surgical debridement procedures.[2,28] In the present study, hyperbaric oxygen was not used because its benefits remain controversial[29]; the treatment itself disturbs other procedures in the acute stage,[12,21] and no consensus protocol for treatment implementation exists.[21] Intravenous immunoglobulin (IVIG) is another adjunct therapy theorized to be of benefit; however, its use in DNI and DNM has been scarcely reported. A recent study of 4127 patients with necrotizing fasciitis showed that IVIG had no effect on mortality or the length of hospital stay.[30] Therefore, though IVIG has its advocates, a consensus regarding its use has not been reached.[29] Further studies are required to precisely define the role of IVIG in DNI and DNM. Vacuum-assisted closure systems have been proven useful in the treatment of DNI[21,31] and DNM.[32,33] In the present study, a vacuum-assisted closure system was utilized to assist with wound healing.

The primary limitations of the current investigation were the small sample size and the retrospective nature of the study; the findings might be less conclusive than those from a prospective study. Future larger, prospective clinical trials are warranted.

Conclusion

We emphasize the need for the integration of a multidisciplinary team (oral and maxillofacial surgeon, infectious disease physician, intensive care specialist, radiologist, anaesthesiologist, otolaryngologist, and thoracic surgeon) for the treatment of DNI associated with DNM. Early and aggressive treatment based on the CT findings may stop further downward expansion of the infection. Less invasive VATS combined with or without catheter interventional therapy is feasible and effective for DNM drainage.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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