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SYSTEMATIC REVIEW

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The assessment and management of deep neck space infections in adults: A systematic review and qualitative evidence synthesis

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Abstract

Objectives: To summarise current practices in the diagnosis and management of deep neck space infections (DNSIs). To inform future studies in developing a framework in the management of DNSIs.

Design: This review was registered on PROSPERO (*CRD42021226449*) and reported in line with *PRISMA* guidelines. All studies from 2000 that reported the investigation or management of DNSI were included. The search was limited to English language only. Databases searched included AMED, Embase, Medline and HMIC. Quantitative analysis was undertaken with descriptive statistics and frequency synthesis with two independent reviewers. A qualitative narrative synthesis was conducted using a thematic analysis approach.

Setting: Secondary or tertiary care centres that undertook management of DNSIs.

Participants: All adult patients with a DNSI.

Main outcome measures: The role of imaging, radiologically guided aspiration and surgical drainage in DNSIs.

Results: Sixty studies were reviewed. Thirty-one studies reported on imaging modality, 51 studies reported treatment modality. Aside from a single randomised controlled trial, all other studies were observational ($n = 25$) or case series ($n = 36$). Computer tomography (CT) was used to diagnose DNSI in 78% of patients. The mean percentage of management with open surgical drainage was 81% and 29.4% for radiologically guided aspiration, respectively. Qualitative analysis identified seven major themes on DNSI.

Conclusions: There are limited methodologically rigorous studies investigating DNSIs. CT imaging was the most used imaging modality. Surgical drainage was commonest treatment choice. Areas of further research on epidemiology, reporting guidelines and management are required.

KEYWORDS

abscess, deep neck space infection, infection, neck infection, parapharyngeal, retropharyngeal

1 | INTRODUCTION

1.1 | Anatomy

The complex structures within the neck are encapsulated by fascial layers, of which the deep cervical fascia plays a vital role. It is subdivided into the following layers[1,2]:

1. Investing/superficial
2. Pretracheal/middle
   - Muscular division
   - Visceral division
3. Prevertebral/deep

Within these layers, the deep neck spaces lie. In vivo, 'space' is a misnomer; the fascial layers lie in contact resulting in only potential space, akin to two sides of a deflated balloon. When infection ensues and there is abscess formation, these fascial layers are then separated by the collection of pus resulting in true spaces (Figure 1).

There are a number of sub-spaces over which there is some contention[3] and can be categorised with relation to the hyoid bone[4,5] (Table 1).

1.2 | Clinical relevance and rationale

Deep neck space infections (DNSIs) have considerable morbidity and mortality. The most serious complications include airway obstruction, descending mediastinitis, great vessel thrombosis, necrotising fasciitis and sepsis.[6–10] Rates of tracheostomy in DNSIs have been reported up to 30%[8] with mortality around 5%.[6]

In the pre-antibiotic era, tonsillitis/pharyngeal infections were the most common cause of DNSIs. Now, however, it is, odontogenic.[11–17] Tonsillitis remains the main paediatric cause.[11,18,19] There is a large number of cases where aetiology appears unknown.[10,17,20–24] Reduced numbers of paediatric tonsillectomy in recent years have been correlated with an increasing frequency of DNSIs in adults.[25] Conversely adult tonsillectomy has also been found to be associated with increased risk of developing a DNSI.[26]

There is limited data on epidemiology of DNSIs. One Asian study reported the incidence of parapharyngeal/retropharyngeal abscess to be 2.64/100 000[27]; however, accurate estimates of the epidemiology of *all* DSNIs and sequelae remain to be fully defined.

Furthermore, debate persists about the best management of DSNIs. There is a consensus on the priorities of ensuring a patent airway, the rapid detection of descending infection, sepsis and other life-threatening manifestations and instigating timely treatment.[5,28,29] The management of early non-life-threatening DSNIs (specifically abscesses) is contentious with some advocating for non-surgical management of some abscesses.[30–33] Similarly, while most advocate some form of imaging to diagnose DSNIs, which modality of imaging and when it is to be undertaken is disputed.[34–36]

Key points

- Deep neck space infections (DNSIs) comprise a selection of diseases.
- Present research on the subject is largely uncontrolled observational case series studies with a universally high risk of bias.
- DNSIs have a significant burden of disease with high complication rates.
- There is a requirement for core outcome measures to be specified to inform future studies on DNSIs.
- Well-designed observational or interventional studies are needed.

1.3 | Aims and objectives

1. To describe the imaging modalities used to diagnose DNSI
2. To describe the management of DNSI

The results from the review will be used to:

1. Inform future research questions in the field of DNSI
2. Inform the development of a treatment algorithm for DNSI

1.4 | Method

The protocol for this review was registered with the York Centre for Reviews and Dissemination PROPSPERO as *CRD42021226449*. The review is reported in line with PRISMA guidance.[37]

1.5 | Eligibility criteria

1.5.1 | Population

All adult patients over the age of 18 years old with a diagnosis of DNSI were included in the review.

1.5.2 | Intervention/comparator

Computer tomography (CT), radiologically guided drainage and surgical management.

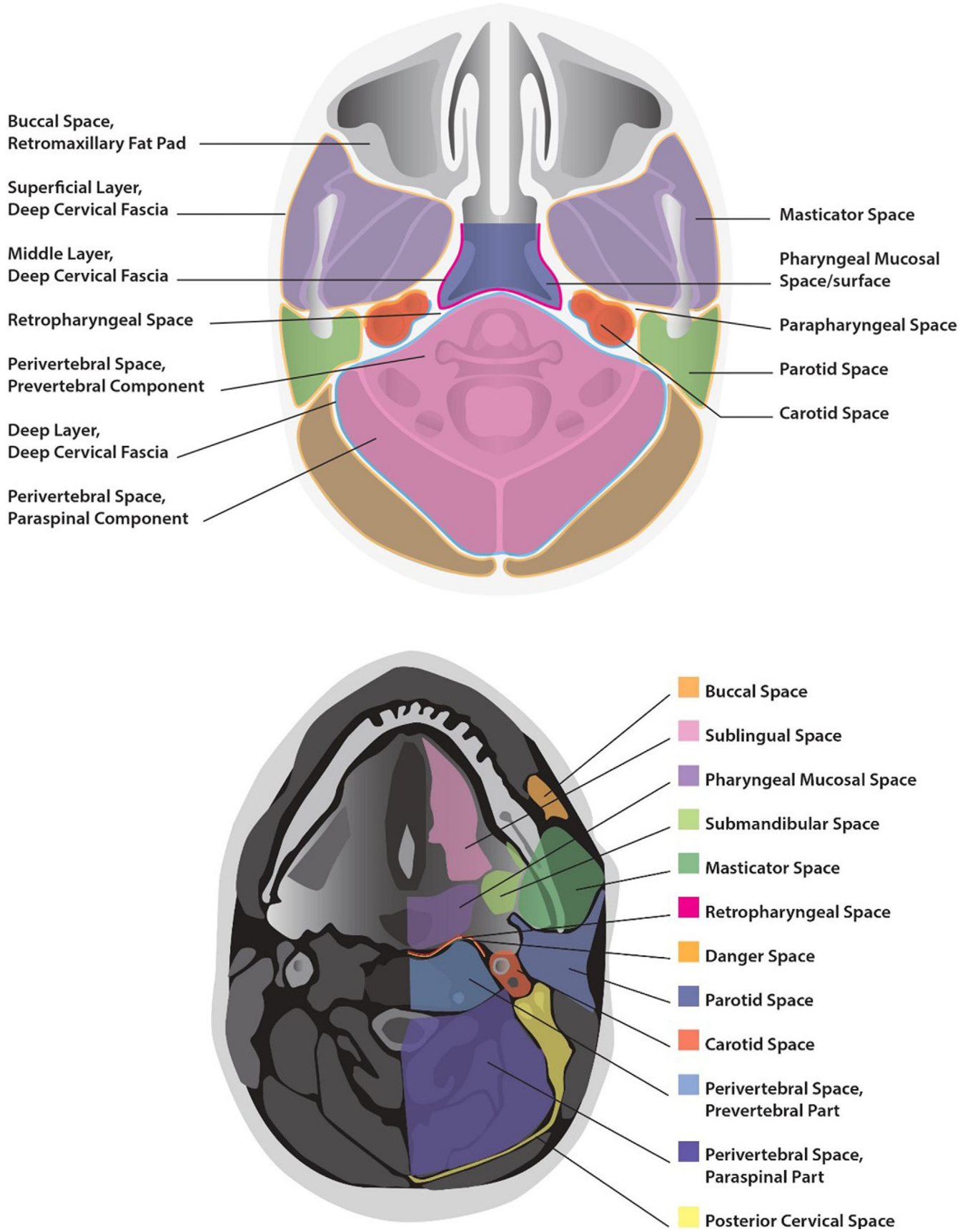

FIGURE 1 Deep neck spaces and relation to fascial layers.

TABLE 1 Deep neck spaces.

Suprahyoid	Supra and infrahyoid	Infrahyoid
Parotid	Carotid/parapharyngeal (post-styloid)	Anterior cervical
Masticator	Retropharyngeal	Suprasternal
Submandibular	Posterior cervical	Strap muscle
Parapharyngral (pre-styloid)	Perivertebral inc pre-vertebral	

1.5.3 | Outcome

The primary outcome of the review was to assess the role of imaging, radiologically guided drainage and open surgical drainage in DNSIs. Secondary outcomes were to assess the frequency, microbiology and outcomes in terms of complications of DNSIs and establish in-depth qualitative data.

1.6 | Information sources

Initially, all observational studies investigating DSNIs present on electronic databases since inception (1964–) will be considered for inclusion; however, this was changed to studies published following the year 2000 because of the advancement and accessibility of axial imaging in emergency surgery.[38,39] The search was limited to English language only. Only published work was considered. For the purposes of this review, DNSI is synonymous with DNS abscess.

The information sources included Medline (since 1946), Embase (1974–), Ovid Emcare (1995–), AMED (1985–) and HMIC (1979–). Searches were conducted in January 2021.

The free text terms in the search strategy included 'deep neck space', 'abscess', named locations of abscesses and imaging modalities. The full search can be seen in Box 1.

1.7 | Selection process

Citations from the searchers were uploaded onto Rayyan, *Bahrain*.[40]

Two independent reviewers (ZS and BY) screened the title and abstracts of all search results with reference to the inclusion/exclusion criteria. Abstracts were categorised into included, not included and might be included.[41]

The full manuscripts of included and may be included abstracts were assessed for inclusion by two other independent reviewers (NQ and EH). The final selection of included studies was then re-referred to the original reviewers (ZS and BY) for final decision. If there was any discrepancy, the supervising reviewer (SQ) acted as the overrule.

BOX 1 Search strategy

Database: AMED (Allied and Complementary Medicine) <1985 to October 2020>, Embase <1974 to 2020 November 12>, Ovid Emcare <1995 to 2020 Week 45>, HMIC Health Management Information Consortium <1979 to September 2020>, Ovid MEDLINE(R) and Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Daily and Versions(R) <1946 to November 12, 2020>

Search Strategy:

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1 deep neck space.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (542)
2 abscess.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (233061)
3 infection.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (4065880)
4 2 or 3 (4219399)
5 parapharyngeal.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (6467)
6 retropharyngeal.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (8416)
7 submandibular.mp. [mp=ab, hw, ti, tn, ot, dm, mf, dv, kw, fx, dq, nm, kf, ox, px, rx, ui, sy] (42306)
8 4 and 5 (1364)
9 4 and 6 (4461)
10 4 and 7 (3196)
11 8 or 9 or 10 (8057)
12 1 and 4 (498)
13 11 or 12 (8298)
14 limit 13 to abstracts (7032)
15 limit 14 to english language [Limit not valid in HMIC; records were retained] (6281)
16 limit 15 to human [Limit not valid in AMED, HMIC; records were retained] (5056)
17 remove duplicates from 16 (3014)

1.8 | Data collection process

NQ and EH independently extracted data from the included studies. NQ collected quantitative data on to a pre-piloted *Microsoft Excel* spreadsheet. EH undertook the narrative synthesis.

1.9 | Data items

For the following quantitative data extraction, the following parameters were defined for collection:

1. Study characteristics
2. Sample size
3. Patient demographics: sex, age, co-morbidities
4. Co-morbidities
5. Aetiology
6. Clinical features
7. Location and size of abscess
8. Imaging—none/ultrasound/CT/MRI
9. Management—antibiotics/aspiration/surgical drainage
10. Efficacy Outcomes, that is, complications, need for further intervention/resolution of condition
11. Missing data—if data was incomplete in any parameters, it would be coded as so.

1.10 | Study risk of bias

Robins-I[42] was used to assess risk of bias; however, it was anticipated that it may not be applicable to certain studies.

1.11 | Effect measures

There was no planned synthesis of data due to the nature of the results reported and therefore no outcome for effect measure was used.

1.12 | Synthesis methods

The primary method for quantitative data analysis was descriptive statistics. Preliminary searches of the literature revealed the data was not amenable to meta-analyses; hence, a qualitative narrative synthesis was undertaken to provide greater depth of meaning to the studies.[43] For the assessment of location of DNSI, studies that included a single space DNSI were excluded to minimise bias. For synthesis, a percentage was taken for each study, for example, 5/10 patients presented with sore throat in one study = 50%, if four studies had a sore throat of 50%, 10%, 20%, and 60%, respectively; the mean percentage of sore throat would be calculated as 35%. This method was used for all parameters in all domains, that is, presentation, aetiology, microbiology and intervention.

The data were tabulated and frequencies of all the parameters were recorded.

The qualitative narrative synthesis was conducted using an inductive approach and thematic analysis in accordance with Braun and Clarke.[44] Thematic analysis of the results sections of the included papers was performed using NVivo (*QSR International, Melbourne*) with themes being generated from codes. From the theme generated by this process, a system of topics produced through discussion between two authors (EGH and ZS).

2 | RESULTS

The search identified 3032 studies and 186 were found to meet the inclusion criteria. After full manuscript review, a further 23 were excluded due to mixed adult and children populations with no differentiation between the samples within the data.

A total of 60 studies were included (Figure 2).

2.1 | Study characteristics

In total, there were 60 studies included in the analysis (Table 2). Studies largely did not report the design, so the methodology was interrogated. These were identified as 1 randomised controlled trial (RCT), 5 prospective cohorts, 33 case series, 10 retrospective cohorts, 6 case–control and 1 cross-sectional study.

2.2 | Bias

The risk of bias was assessed using ROBINS-I tool for the observational studies; they were all deemed to have a serious or critical risk of bias due to study design.

2.3 | Study results

Overall, 60 studies were reviewed including a total of 103 320 patients. Thirty-one studies reported imaging modality and 51 reported on treatment modality (antibiotics, aspiration or surgical drainage).

2.3.1 | DNSI location

In the studies that reported more than 1 location of DNSIs, the most common location was the submandibular space ($n = 1578$), followed by parapharyngeal ($n = 660$) and peritonsillar ($n = 598$) (Figure 3).

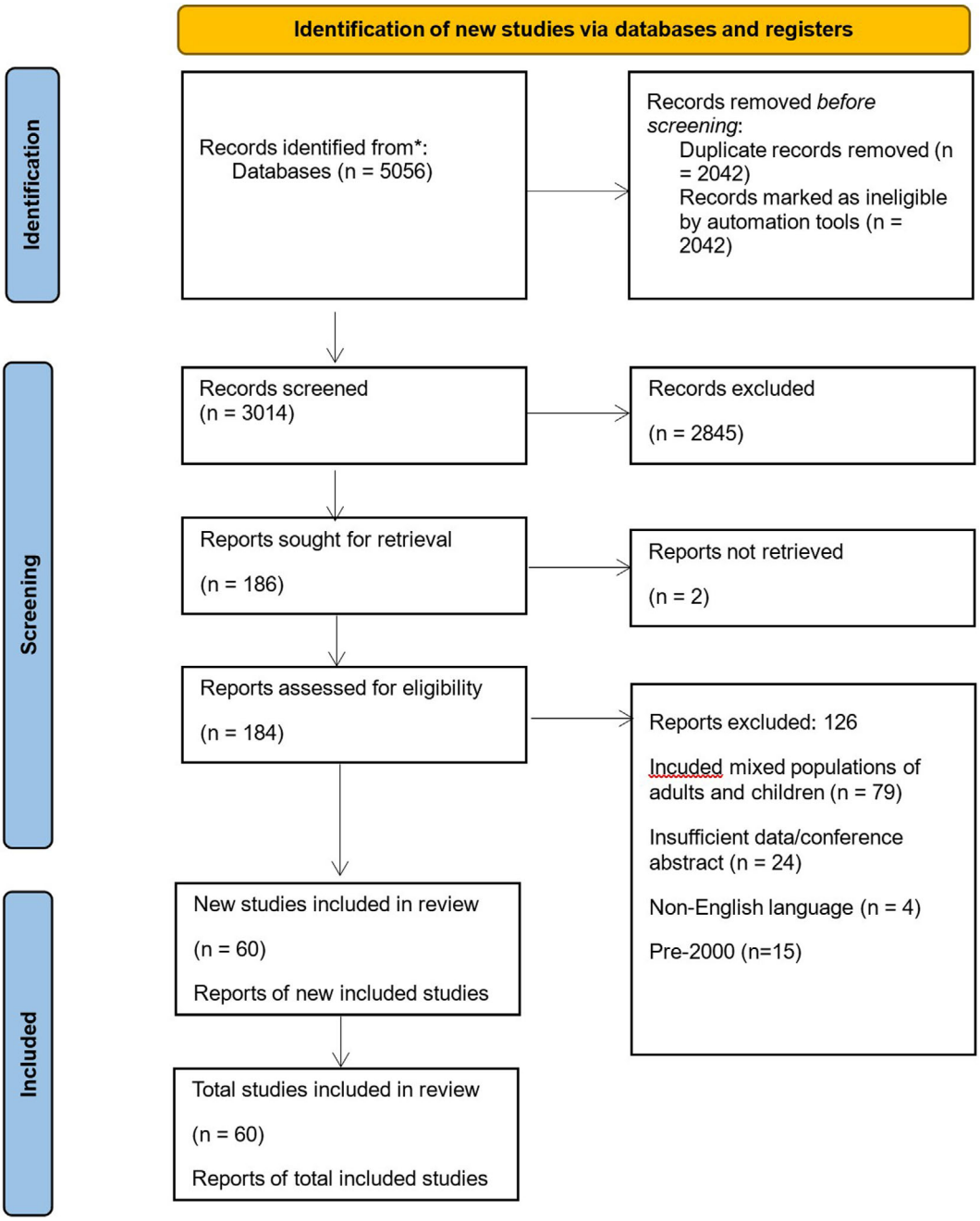

FIGURE 2 PRISMA study flow chart.

2.3.2 | Presentation/clinical features

Sixteen studies reported clinical features of DNSI. Odynophagia (13 studies) and airway compromise (11 studies) were the most commonly reported clinical features. Only three studies reported on sore throat.

Mean percentages of all patients suggest that the most common clinical feature for the presentation of DNSI is neck pain/rigidity at 84.7%, followed by neck swelling at 78.3%. Airway compromise was found to be 24.7%.

2.3.3 | Aetiology

Twenty-eight studies reported aetiology findings. Twenty-six studies reported dental infections leading to DNSI and were found to be the

TABLE 2 Study characteristics.

Study	Year	Study design	Sample size	Aims and summary
Adovica et al.[45]	2017	Retrospective cohort	263	In patients hospitalised due DNSIs, to investigate association between demographic parameters, aetiology and localisation of abscesses and/or phlegmons, complications, comorbidities, treatment and bacterial cultures.
Alaani et al.[46]	2005	Case series	5	We present five cases of parapharyngeal abscess resulting from tonsillitis and peritonsillar infection extending to the parapharyngeal space in adult patients.
Ariji et al.[47]	2002	Case series	33	To determine the pathways of odontogenic infection spread into the submandibular space and their relationship to the clinical symptoms.
Aziz et al.[48]	2020	Cross-sectional	17	To carry out a cross-sectional analysis of infections of the deep neck space and to analyse various aspects of the deep neck space infections including symptoms, aetiology, diagnostic investigations, threatening complications and management plan for each type of deep neck space infections.
Barber et al.[49]*	2014	Case–control	25	To determine factors predictive of a severe deep neck space infection (DNSI), defined as those requiring surgery and/or postoperative intensive care unit (ICU) admission. To specifically examine dental practices and socioeconomic factors that may contribute to the development of a DNSI.
Barber et al.[49]*	2014	Case–control	233	To determine factors predictive of a severe deep neck space infection (DNSI), defined as those requiring surgery and/or postoperative intensive care unit (ICU) admission. To specifically examine dental practices and socioeconomic factors that may contribute to the development of a DNSI.
Beka et al.[50]	2019	Case series	564	To determine, from October 2010 to October 2018, the epidemiology of Deep Neck Infections (DNIs), regarding the detection, the identification and the susceptibility to antimicrobials of causative microorganisms, in Thessaly-Central Greece.
Benaixa et al.[51]	2007	Case series	17	Retrospective study conducted of 25 cases of peripharyngeal (lateropharyngeal and/or retropharyngeal) abscesses diagnosed and treated between January 1999 and November 2005 according to the protocol for diagnosis and treatment of peripharyngeal abscesses.
Benmansour et al.[52]	2012	Case series	4	To review the clinic features, diagnostic tools and management of retropharyngeal abscesses in adults.
Biron et al.[53]	2013	Randomised control trial	17	To compare I&D versus USD of well-defined DNAs, using a randomised controlled clinical trial design.
Blochowiak et al.[54]	2018	Case series	5	Based on clinical presentations, the possible complications and results of different methods of treatment were described. We present five cases of non-odontogenic deep neck infections.
Bottin et al.[55]	2003	Case series	83	To review the experience of the Department of Otolaryngology and Head and Neck Surgery of Padua with deep neck infections during the period from 1998 to 2001.
Brito et al.[23]	2016	Case series	74	To present our clinical-surgical experience with deep neck abscesses.
Bross-Soriano et al.[56]	2004	Case series	121	To review Ludwig's angina medical and surgical approach with small incisions.
Chi et al.[57]	2014	Case series	14	To analyse the clinical features, radiological findings, treatment modalities, and microbiology of parotid abscesses treated at a regional hospital in Taiwan over a 15-year period.
Cramer et al.[58]	2016	Cohort study	347	The conventional treatment for deep neck abscesses in adults is antibiotic therapy with surgical drainage, whereas in children there is debate about the role of surgical drainage versus conservative therapy. It is presently unclear if delayed surgical drainage negatively affects outcomes.
Dabirmoghaddam et al.[32]	2017	Case–control	60	To compare ultrasound-guided drainage of neck abscesses with incision and drainage.
Favaretto et al.[59]	2015	Retrospective cohort	235	To review our experience of the diagnosis and treatment of DNIs of salivary gland origin. We also compared the characteristics of DNIs originating from salivary glands with those originating elsewhere.
Franzese and Isaacson[60]	2003	Case series	14	To review the presentation and management of peritonsillar (PTA) and parapharyngeal space (PPSA) abscesses in older adults and compare this with the usual presentation and management in the younger patient.

(Continues)

TABLE 2 (Continued)

Study	Year	Study design	Sample size	Aims and summary
Freling et al.[61]	2009	Case series	61	To assess the predictive value of the diagnosis of deep neck abscess using CECT.
Garcia et al.[62]	2012	Retrospective cohort	54	To identify ICU admission variables that were able to predict severe infection or a complicated course and to assess whether severe infection was associated with a complicated course in DNIs drained surgically and admitted to the ICU.
Harkani et al.[63]	2011	Case series	5	We report five cases of retropharyngeal abscess.
Hasegawa et al.[11]	2011	Retrospective cohort	59	To clarify the clinical risk factors that aggravate deep neck infection.
Hirai et al.[64]	2005	Case series	8	To evaluate the clinical significance of Streptococcus milleri group (SMG) in head and neck infections.
Hirasawa et al.[65]	2017	Case–control	17	To examine which cases of deep neck infection were less likely to achieve cure and to clarify the limitations of conservative treatment for deep neck cellulitis.
Huang et al.[66]	2006	Case–control	212	To analyse the bacteriology in deep neck infections and identify the factors that influenced the causative pathogens.
Hurley et al.[67]	2018	Case series	74	To assess demographics of patients presenting with DNSI and the financial burden to the National Health Service (NHS).
Hyun et al.[30]	2014	Case series	30	To evaluate usefulness of closed suction drainage for DNI.
Iwata et al.[68]	2005	Case series	10	To evaluate our treatment strategy for descending necrotising mediastinitis.
Kauffman et al.[8]	2017	Cohort	63	To review the +E31:E40 clinical course and the management of deep neck infections in our department, compare them to the experiences of the common literature and identify predisposing factors for lethal complications.
Kinzer et al.[69]	2009	Case series	10	To determine clinical, diagnostic and therapeutic aspects of severe neck infections of odontogenic origin.
Kumar[70]	2015	Case series	10	Ten cases of adult retropharyngeal abscess were reviewed.
Larawin et al.[6]	2006	Case series	65	To evaluate incidence, causes, management and complications of different head and neck space infections in a Melanesian population.
Lee et al.[71]	2010	Case series	131	To review our experience with deep neck abscesses, identify key trends and improve management of this condition.
Maharaj et al.[72]	2019	Case series	52	We studied the clinical presentation and microbiology of patients with deep neck space infection in a developing nation to aid in determining the relevant, appropriate, and effective empirical antimicrobial treatment. We have also described the demographic data of paediatric versus adult patients and the predominant age-related subtypes of deep neck space infections.
Mayor et al.[73]	2000	case series	31	A 31-patient prospective series on deep neck infections, managed at Hospital Ramo´n y Cajal in Madrid, Spain, is presented.
McDonnough et al.[74]	2019	Case series	5855	To describe the epidemiological characteristics of Ludwig's angina patients presenting to the emergency department (ED) and to examine outcomes and resource utilisation to determine their burden on ED and hospitals.
Meijzlik et al.[75]	2017	Case–control	586	To identify deep neck infection factors related to life-threatening complications.
Crespo et al.[76]	2004	Case series	65	To compare clinical and computed tomography findings from neck spaces affected by deep neck infections and to determine main clinical and radiological features associated with these.
O'Brien et al.[77]	2020	Retrospective Cohort	163	To analyse risk factors affecting length of stay (LOS) for patients presenting with deep neck space infections including care by medical versus surgical team.
Panduranga Kamath et al.[78]	2003	Case series	4	To study presentation, aetiology, microbiology and morbidity of DNSI.
Poluri et al.[79]	2000	Case series	3	To aid recognition and management of foreign body associated complications.
Qureshi et al.[80]	2015	Retrospective cohort	91 647	To describe national trends in retropharyngeal abscess complicating peritonsillar abscess and to determine factors associated with RPA in patients with PTA.
Ridder et al.[7]	2005	Case series	13*	To study clinical course and outcome DNIs with special emphasis on microbiology and histopathology. *only 13 patients had extractable data

TABLE 2 (Continued)

Study	Year	Study design	Sample size	Aims and summary
Riekert et al.[81]	2019	Retrospective cohort	499	To evaluate perioperative risk factors concerning difficult airway management, primary tracheostomy, and need for ICU admission in severe odontogenic space infections.
Rzepakowska et al.[82]	2019	Retrospective cohort	46	We analysed treatment protocols of 46 adults to assess efficacy of the treatment and search for prognostic factors of the outcomes.
Schuknecht et al.[83]	2008	Case series	29	To analyse pathways of spread in 30 patients with odontogenic masticator space abscess.
Schuler et al.[84]	2009	Case series	5	To assess the risks and benefits of surgical intervention in patients with RPA.
Sharma et al.[85]	2014	Case–control	78	To determine which clinical, microbiological and radiological factors contribute to the need for repeated computed tomography (CT) imaging and surgical drainage.
Shimizu et al.[86]	2017	Cohort study	108	To reveal the clinical differences between DNIs in children and adults.
Sichel et al.[87]	2002	Case series	1*	A prospective study on all patients with an infection limited to the parapharyngeal space.
Sittitrai et al.[88]	2018	Cohort study	223	To compare the clinical features, complications, and outcomes of deep neck infections in patients with and without the human immunodeficiency virus (HIV).
Stan et al.[89]	2014	Case series	21	To develop an algorithm for the diagnosis and treatment of cervical phlegmons in order to increase the diagnostic accuracy, to reduce the intra and post-operative risks and complication rates and to increase the number of cases with restitutio ad integrum.
Tapiovaara et al.[90]	2017	Retrospective cohort	202	We retrospectively evaluated adult DNIs in a single tertiary centre covering 10 years, with special attention on airway management.
Terzic and Scolozzi[91]	2013	Cohort study	81	To describe and analyse DNI of purely dental origin involving on one hand SM and on the other hand infections without presence of SM.
Tiefel et al.[92]	2021	Case series	100	To equip NPs with information to accurately diagnose and appropriately manage patients with a PTA. This article describes the most common characteristics of the patient who presents to outpatient providers with unilateral throat pain consistent with a diagnosis of PTA.
Vallee et al.[93]	2020	Case series	4	We present four cases of severe necrotizing cervical cellulitis notably associated with concomitant self-medication with non-steroidal anti-inflammatory drugs.
Wang et al.[36]	2014	Case series	28	To investigate the images of deep neck space infection of phlegmon and abscess and the role of imaging examination in correct localisation and treatment.
Yang et al.[94]	2015	Cohort study	86	To present our experience of the clinical course and management of deep neck infection and try to determine if the characteristics of this kind of infection were similar between the children and adults in southern China.
Ye et al.[95]	2017	Case series	100	To evaluate the prevalence and antimicrobial susceptibility, of aerobic and anaerobic strains in 100 patients with head and neck (single and multiple) abscesses.
Zirk et al.[96]	2020	Retrospective cohort	350	To investigate if cefazolin can be an appropriate perioperative intravenous antibiosis in patients suffering from severe odontogenic neck infection descending from the lower jaw.

most common cause at 47.7%. This was followed by the other/miscellaneous category at 22.3%, which included causes such as trauma, adenitis, cysts, malignancy and insect bites. This is followed by oropharyngeal infections at 21.2%.

2.3.4 | Co-morbidities

Twenty-eight studies reported co-morbidities. The most commonly reported co-morbidity was diabetes mellitus (type 1 or 2) at 16.1%. Smoking, however, was more prevalent, from 10 studies, 41.6% of patients were found to be smokers.

2.3.5 | Microbiology

One hundred thirteen different micro-organisms cultured from DNSI were reported from 28 studies. The most common Gram-positive organisms were *Staphylococcus aureus* (11.06%), followed by *S. viridans* (9.71%), *Peptostreptococcus* (7.83%),

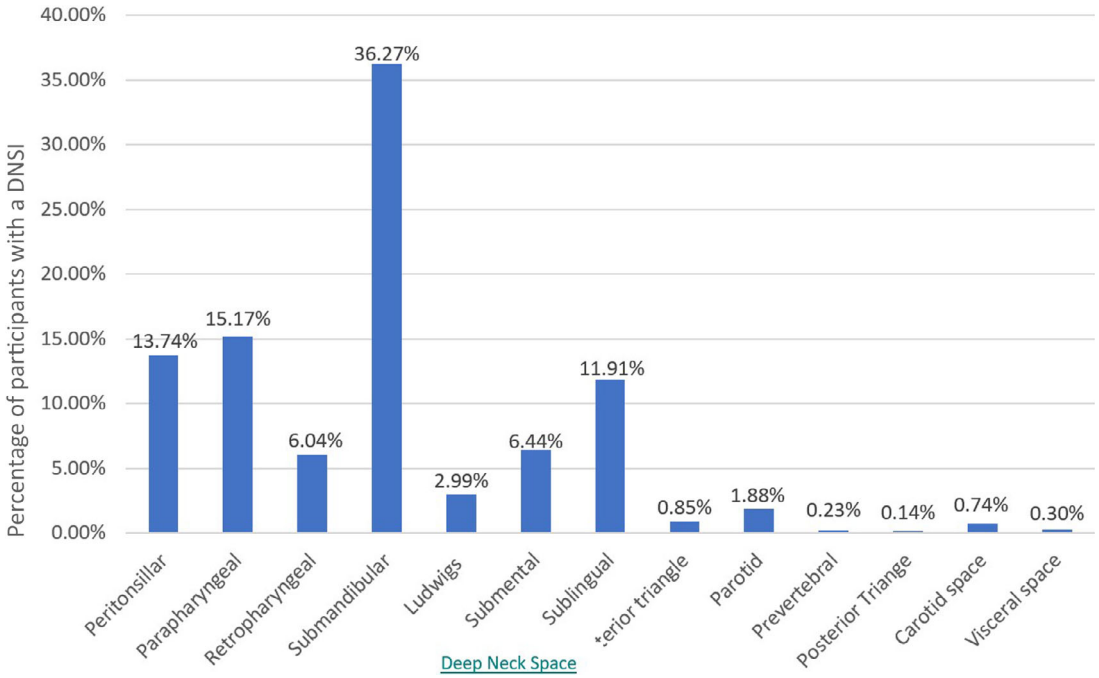

FIGURE 3 Location of DNSI in participants with a DNSI in included studies that reported more than one DNSI.

S. anginosus (7.26%), *S. milleri* (7.26%) and *S. pyogenes* (7.15%). Polymicrobial infections were also present (6.95%) as well as no growth (4.42%). In terms of Gram-negative, the most common organisms were *Klebsiella pneumoniae* (4.42%), *Bacteroides* unspecified (3.26%) and *Escherichia coli* (2.03%) and other/unidentified (5.08%) (Figure 4).

2.3.6 | Imaging

Forty-five studies reported imaging modality; CT was the most commonly used modality at 90.5%, followed by US at 38.4% and MRI at 34% of patients (Figure 5). Fourteen studies reported using more than 1 modality of imaging. Five studies reported using plain radiographs, of which only one specified they used an orthopantomogram with data. Two further studies have stated that orthopantomograms were used but did not report any data and two studies used only plain radiographs with no other imaging modality.

2.3.7 | Intervention/treatment modalities

Fifty-one studies assessed intervention and treatment modalities with adult-only data. Fifteen studies reported radiologically guided drainage as treatment (with or without subsequent open surgical drainage). Fifty studies reported open surgical drainage as the only treatment or after initial treatment with medical management or radiologically guided aspiration. The mean percentage of management of the 51 studies with open surgical drainage was 81% and 29.4% for radiologically guided aspiration, respectively (Figure 6).

The recovery rate for radiologically guided drainage without further intervention was 75.4%. Including further intervention, the recovery was 91.75%, of which 57.7% of these patients required further intervention (either radiologically guided drainage or open surgical drainage). Recovery after open surgical drainage was 96.9%, and of these patients, 42.3% required a second intervention. Eleven studies reported mortality with a mean of 7.9% and a range of 0.01%–13.3% (Table 3).

2.4 | Results—Qualitative Narrative Synthesis

Seven topics on DNSI were identified: aetiology, clinical features, investigations, management, complications, economic burden and specialities involved in care. These topics and their themes are discussed below. Selected quotations to illustrate each theme are provided in Table 4. Figure 7 shows the thematic schema demonstrating the relationships between the topic and themes:

1. Aetiology: *Streptococci* sp. was the most common causative organism.
2. Neck space: submandibular and parapharyngeal were most common. However, Ludwig's was not mentioned.
3. Causes of DNSI infection: most commonly due to tonsillar/peritonsillar and dental sources.
4. Symptoms: neck swelling appeared to be the most common along with a sore throat, trismus and some form of respiratory distress.

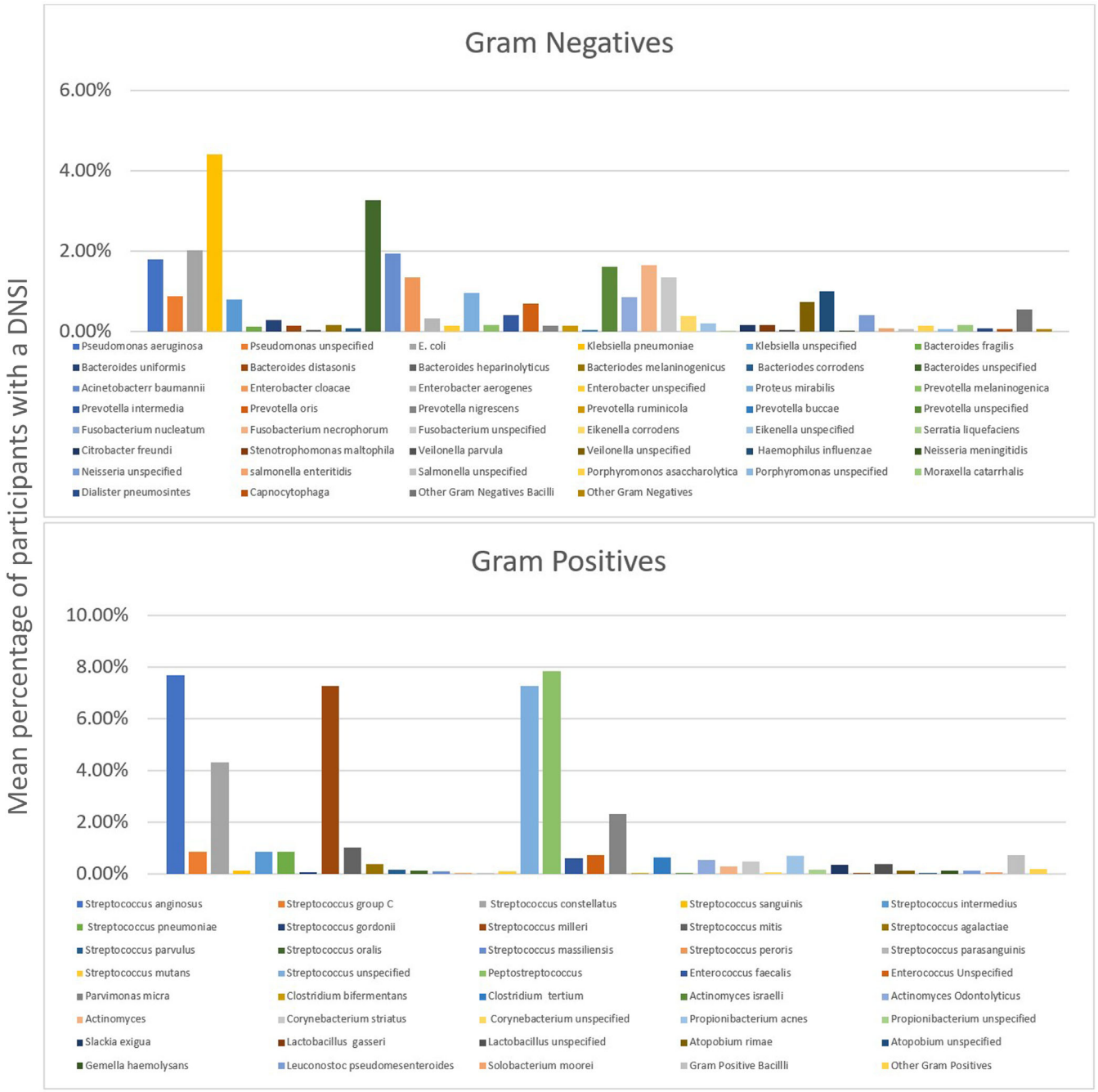

FIGURE 4 Identified organisms from DNSI.

5. Investigations: multiple imaging techniques were used alongside serology, but CT scanning appeared to be used most commonly to confirm diagnosis.
6. Management:
   - Pre-hospital: most patients had been given a course of antibiotics prior to presentation to secondary care
   - Airway: endotracheal intubation and tracheostomy were required in multiple cases
   - Surgical: there was a combination of aspiration (radiologically guided and non-guided) and incision and drainage. Most patients required definitive incision and drainage; however, aspiration proved successful in some
   - Non-surgical: intravenous antibiotics in the form of cephalosporins and metronidazole appeared to most commonly used, followed by amoxicillin/clavulanic acid. Steroids were frequently used
7. Complications: included airway compromise, great vessel thrombosis, sepsis and mediastinitis. Mortality is present, not frequent.
8. Economic burden: there is a significant cost to management with patients with DNSI.

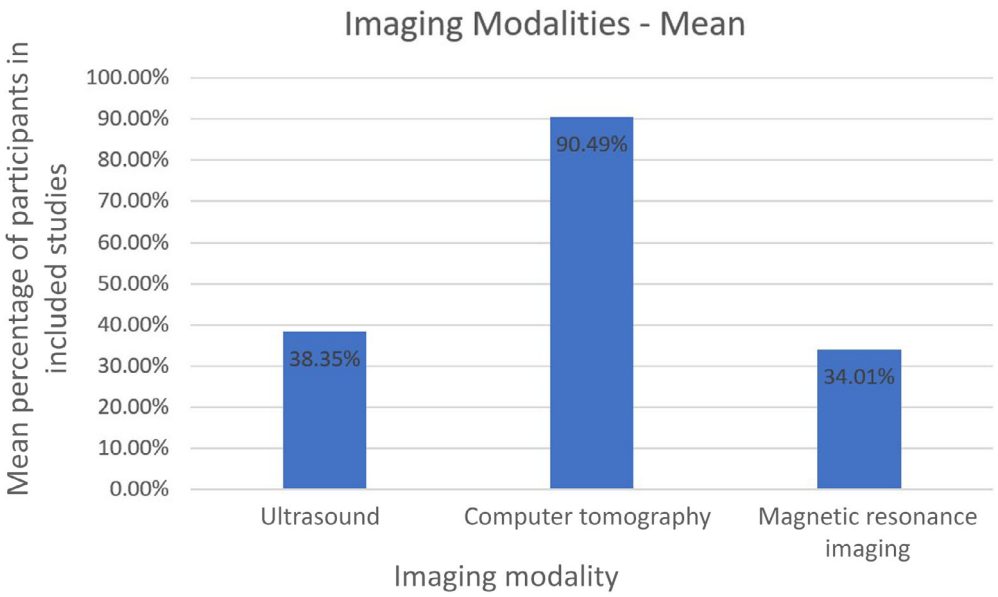

FIGURE 5 Imaging modalities.

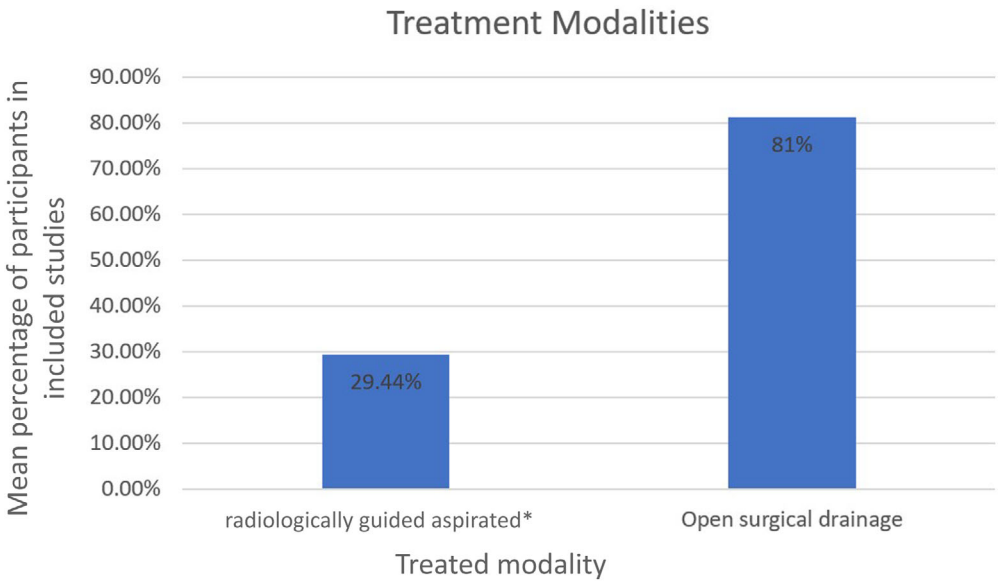

FIGURE 6 Treatment modalities.

3 | DISCUSSION

3.1 | Summary of the results and reference to literature

The results show that there is great variability of what is reported in the literature. Although 60 studies were included in the final analysis, there were significant discrepancies in which aspects of DNSI were investigated and which data was reported. Additional studies could have been included however they failed to differentiate the data between children and adults.

Currently, there are no *systematic* reviews on the treatment of DNSI in adults. The only interventional study was an RCT. Studies included in the review did not report data on epidemiology of DNSI as a collective; the format of the included studies was case series assessing frequencies in their own practice or large sample studies of a single space infection such as Ludwigs Angina (McDonnough et al., $n = 5855$) or parapharyngeal abscess as a complication of peritonsillar abscess (Qureshi et al., $n = 91\,647$).

3.2 | Limitations of study evidence

The greatest methodological flaw arises from the included studies was study design. Most were case series ($n = 36$). The observational studies largely did not state their study design. Therefore the levels of evidence of studies included in this review are in the lower tiers of all parameters of evidence reporting in the literature

TABLE 3 Intervention details.

Study	Population	No patients	Aspiration	Aspiration % only	Surgery	Surgery % only	Efficacy
Adovica et al.[45]	Adults with deep neck space phlegmons/abscesses	263			246/263 (93.54%)	93.54%	Insufficient data regarding recovery or need for further procedures
Alaani et al.[46]	Adults with parapharyngeal abscesses	5	3/5 (60%)	60%	Surgery 3/5 (60%) (2/5 (40%) initial surgery and 1/5 (20%) after initial aspiration failed)	40%*	Aspiration: 2/3 (66.7%) recovered; 1/3 (33.3%) required surgical management and recovered Surgery: 3/3 (100%) recovered (1/3 [33.3%] recovered after initial surgery; 2/3 [66.67%] needed further surgical management)
Aziz et al.[48]	Adults with deep neck space infections	17			13/17 (76.47%)	76.47%	
Barber et al.[49]	Adults with deep neck space infection	233	20/233 (8.58%)	8.58%	180/233 (68.8%)	68.80%	Medicine 27/27 (100%) recovered Radiologically guided aspiration 20/20 (100%) recovered Surgery 180/180 (100%) recovered
Benaixa et al.[51]	Adults with parapharyngeal abscesses	17	7/17 (41.18%)	41.18%	4/17 (23.53%) (all after aspiration failed)	23.53%	Medicine 10/10 (100%) recovered Aspiration 2/7 (28.57%) recovered after initial aspiration, 1/7 (14.3%) recovered after 2 aspirations, 4/7 (57.1%) required surgical drainage Surgery 4/4 (100%) recovered
Benmansour et al.[52]	Adults with retropharyngeal abscesses	4			4/4 (100%)	100%	Surgery 4/4 (100%) (no data on need for repeat procedures)
Biron et al.[53]	18–65 year-olds with CT-proven deep neck space abscess	17	8/17 (47.06%)	47.06%	9/17 (53.94%)	53.94%	Radiologically guided aspiration 8/8 (100%) recovered Surgery 9/9 (100%) recovered
Blochowiak et al.[54]	Adults with non-odontogenic deep neck space infections	5	2/5 (40%)	40%	3/5 (60%)	60%	Insufficient data regarding recovery or need for further procedures
Bottin et al.[55]	Adults with deep neck space infection	83			57/83 (68.67%)	68.67%	Insufficient data regarding recovery or need for further procedures.
Bross-Soriano et al.[56]	Adults with Ludwig's angina	121			121/121 (100%)	100%	Surgery 110/121 (90.9%) recovered (11/121 [9.09%] mortality); no data on need for repeat procedures
Chi et al.[57]	Adults with CT-proven parotid abscesses	14			14/14 (100%)	100%	Surgery 14/14 (100%) recovery (no data on need for repeat procedures)
Cramer et al.[58]	Adults with deep neck space infections	347			347/347 (100%)	100%	Surgery 345/347 (99.42%) recovery (2/347 [0.01%] mortality; 19/347 (5.48%) required further surgery)
Dabirmoghaddam et al.[32]	Adults with CT-proven well-define neck abscesses. Excluded: Authors	60	30/60 (50%)	50%	30/60 (50%)	50%	Radiologically guided aspiration 25/30 (83.3%)

(Continues)

TABLE 3 (Continued)

Study	Population	No patients	Aspiration	Aspiration % only	Surgery	Surgery % only	Efficacy
	excluded patients who were pregnant or who had: evidence of airway compromise, a multi-loculated or ill-defined abscess, a recurrent neck abscess, contraindications to surgery, coagulopathy, an immune-suppressing medical condition, or evidence of a neck neoplasm.						recovered (5/30 (16.7%) had repeat aspiration) Surgery 30/30 (100%) recovered (3/30 [10%] had repeat surgical drainage)
Favaretto et al.[59]	Adults with DNIs originating from salivary glands and adults with DNIs originating from non-salivary gland sources	235			153/235 (65.1%)	65.10%	Insufficient data regarding recovery or need for further procedures.
Franzese and Isaacson[60]	Patients aged 50 and above with PTAs and PTAs with concomitant PPSAs	14	6/14 (42.9%)	42.90%	8/14 (57.14%)	57.14%	Aspiration 6/6 (100%) recovery Surgery 8/8 (100%) recovery
Freling et al.[61]	Adults with clinical and radiological (CT) suspicion of DNSI	61	8/61 (13.11%)	13.11%	41/61 (67.21%)	67.21%	Medicine 14/14 (100%) recovery Aspiration 6/8 (75%) recovery 2/8 (25%) required further surgical drainage, Insufficient data regarding recovery Surgery: Insufficient data regarding recovery or need for further procedures.
Garcia et al.[62]	Adult admitted for surgical drainage of deep neck infections and admitted to the intensive care unit	54			54/54 (100%)	100%	Surgery 49/54 (91%) (5/54 [9%] mortality) insufficient data regarding need for further procedures
Harkani et al.[63]	Adults with retropharyngeal abscesses	5	3/5 (60%)	60%	2/5 (40%)	40%	Aspiration 3/3 (100%) recovery Surgery 2/2 (100%) recovery
Hirai et al.[64]	Adults with DNSI caused by Streptoccus milleri group	8			7/8 (87.5%)	87.50%	Medicine 1/1 (100%) recovery Surgery 7/8 (100%) (insufficient data regarding need for further procedures)
Hirasawa et al.[65]	Adults with deep neck space cellulitis	17			10/17 (58.82%) (all failed medical management)	58.82%	Medicine 7/17 (42.18%) recovery; 10/17 (58.82%) required surgery Surgery 10/10 (100%)
Hurley et al.[67]	Adults with DNSI	74			55/74 (74.32%)	74.32%	Medicine insufficient data regarding outcomes Surgery 11/55 (20%) required more than one operation; insufficient data regarding outcomes
Hyun et al.[30]	Adults who underwent incision and drainage for DNSI	30			30/30 (100%)	100%	Surgery 26/30 (86.7%) recovery (4/30 [13.3%] mortality)

TABLE 3 (Continued)

Study	Population	No patients	Aspiration	Aspiration % only	Surgery	Surgery % only	Efficacy
Iwata et al.[68]	Adults with descending necrotizing mediastinitis	10			10/10 (100%)	100%	Surgery 8/10 (80%) recovery (2/10 [20%] mortality), 1/10 (10%) need for second thoracotomy
Kauffman et al.[8]	Adults with DNSI who were treated surgically	63			63/63 (100%)	100%	Surgery 61/63 (97%) recovery (2/63 [3%] mortality)
Kinzer et al.[69]	Adults with severe DNSIs of odontogenic origin	10			10/10 (100%)	100%	Surgery 10/10 (100%) recovery, 6/10 (60%) need for additional surgery
Kumar[70]	Adults with retropharyngeal abscesses	10	1/10 (10%)	10%	10/10 (100%)	100%	Insufficient data regarding recovery or need for further procedures
Lee et al.[71]	Adults with deep neck space abscesss	131	17/131 (12.98%)	12.98%	108/131 (82.44%)	82.44%	Insufficient data regarding recovery or need for further procedures
Mayor et al.[73]	Adults with parapharyngeal or retropharyngeal infections	31			3/31 (9.68%)	9.68%	Medicine 28/31 (87.1%) recovery; 3/31 (9.68%) required further surgery Surgery 3/3 (100%) recovery insufficient data regarding need for further procedures
McDonnough et al.[74]	Adults with Ludwig's angina	5855			2766/5855 (47.24%)	47.24%	Insufficient data regarding recovery or need for further procedures
Meijzlik et al.[75]	Adults with deep neck space infection	586			586/586 (100%)	100%	Surgery 583/586 (99.5%) recovery (3/586 [0.5%] mortality), insufficient data regarding need for further procedures
Crespo et al.[76]	Patients with DNSI	65	4/65 (6.15%)	6.15%	65/65 (100%)	100%	Aspiration 0/4 (0%) recovery (4/4 [100%] need for further surgery) Surgery 60/65 (92.3%) recovery (5/65 [7.7%] mortality)
O'Brien et al.[77]	Adults with deep neck space infection	163			123/163 (75.46%)	75.46%	Medicine 40/40 (100%) recovery (7/40 [17.5%] re-admitted but no surgery) Surgery 123/123 (100%) recovery (13/123 [10.57%] re-admitted, but no further surgery)
Panduranga Kamath et al.[78]	Adults with deep neck space abscesses	4			4/4 (100%)	100%	Surgery 3/4 (75%) recovery (1/4 [25%] mortality)
Poluri et al.[79]	Adults with retropharyngeal abscesses secondary to foreign bodies	3			3/3 (100%)	100%	Surgery 3/3 (100%) recovery
Qureshi et al.[80]	Adults with PTA and with retropharyngeal abscess associated with PTA	91 647			49 980/91 647 (54.54%)	54.54%	Insufficient data regarding recovery or need for further procedures.
Ridder et al.[7]	Adults with DNSIs caused by malignant tumours	13	2/13 (15.38%)	15.38%	10/13 (76.92%)	76.92%	Insufficient data regarding recovery or need for further procedures.
Riekert et al.[81]	Adults with severe DNSIs of odontogenic origin	499			499/499 (100%)	100%	Insufficient data regarding recovery or need for further procedures.

(Continues)

TABLE 3 (Continued)

Study	Population	No patients	Aspiration	Aspiration % only	Surgery	Surgery % only	Efficacy
Rzepakowska et al.[82]	Adults with DNSI who were treated surgically	46			46/46 (100%)	100%	Surgery 44/46 (95.7%) recovery (2/46 [4.3%] mortality, 2/64 [4.3%] need for further surgical management)
Schuknecht et al.[83]	Adults with masticator space abscess derived from odontogenic infection	29			27/29 (93.1%)	93.10%	Insufficient data regarding recovery or need for further procedures
Schuler et al.[84]	Adults with retropharyngeal abscesses	5			5/5 (100%)	100%	Surgery 5/5 (100%) recovery (2/5 [40%] needed further surgical management)
Sharma et al.[85]	Patients who underwent surgical drainage of cervicofacial infections	78			78/78 (100%)	100%	Surgery 9/78 (11.5%) required further surgery (insufficient data regarding recovery)
Shimizu et al.[86]	Adults with DNSIs	108			108/108 (100%)	100%	Surgery 105/108 (97.22%) recovery (3/108 [2.78%] mortality) insufficient data regarding further surgery
Sichel et al.[87]	Adults with parapharyngeal space infection	1					Medicine 1/1 (100%) recovery
Sittitrai et al.[88]	DNSIs in adults with and without HIV	223			202/223 (90.58%)	90.58%	Insufficient data regarding recovery or need for further procedures
Stan et al.[89]	Adults with parapharyngeal and retropharyngeal phlegmon	21			21/21 (100%)	100%	Surgery 21/21 (100%)
Tapiovaara et al.[90]	Adults with DNSIs	202			202/202 (100%)	100%	Surgery 200/202 (99.01%) recovery (2/202 [0.99%] mortality) (44/202 [21.78%] need for further surgery)
Terzic and Scolozzi[91]	Patients with deep neck space abscesses of dental origin (comparing those with SMG with those without SMG)	81			81/81 (100%)	100%	Surgery 81/81 (100%) recovery (insufficient data on need for repeat procedures)
Vallee et al.[93]	Adults with necrotizing cervical cellulitis	4	1/4 (25%) (after initial incision and drainage)	25%	4/4 (100%)	100%	Radiologically guided aspiration 1/1 (100%) recovery Surgery 3/4 (75%) recovery (4/4 [100%] need for further intervention: 1/4 [25%] Radiologically guided aspiration, 3/4 [75%] further surgery)
Wang et al.[36]	Adults with DNSI	28			13/28 (46.43%)	46.43%	Medicine 15/15 (100%) recovery Surgery 13/13 (100%) recovery
Yang et al.[94]	Adults with DNSI	86	8/86 (9.3%)	9.30%	49/86 (56.98%)	56.98%	Insufficient data regarding recovery or need for further procedures
Zirk et al.[96]	Adults with severe odontogenic neck infection descending from the lower jaw	349			350/350 (100%)	100%	Surgery insufficient data regarding recovery; 15/350 (4.29%) need for further procedures.
Mean				29.44%		81%	

TABLE 4 Thematic analysis topics and themes.

Themes	Subthemes	Quote	References
Aetiology	Organism	The most common microbe isolated from surgical specimens or aspirates was *Streptococcus anginosus* (40%), followed by *Streptococcus pyogenes* (12%) and *Staphylococcus aureus* (12%).	Barber et al.[49]
		The original organisms were Streptococci in seven cases, Peptostreptococci in four cases, Bacteroides in two cases and Prevotella in two cases. In seven cases, aerobic and anaerobic organisms were mixed.	Iwata et al.[68]
		The cultures of 46 patients (35.9%) were polymicrobial. The most common organism was viridans Streptococcus (38.3%), followed by *Klebsiella pneumoniae* (32.0%), Peptostreptococcus (17.2%), Neisseria species (9.4%), b-hemolytic streptococci (7.8%) and *Staphylococcus aureus* (7.8%). Anaerobic bacterial infection was found in 38 patients (29.7%).	Huang et al.[66]
	Neck space	The site of infection was most commonly the parapharyngeal space ($n = 45$, 60.8%). Twelve patients (16.2%) had infection in the retropharyngeal space while eight (10.8%) had infection in the submandibular space. In nine cases (12.6%), there were infections in multiple spaces.	Hurley et al.[67]
		Abscess locations, based on CT images were: peritonsillar (82%), parapharyngeal (37%) and retropharyngeal (26%). Thirty per cent of the patient had multiple site abscesses.	Garcia et al.[62]
		The most common site involved was submandibular space (20/46), followed by parapharyngeal space (13/46) and carotid space (9/46).	Rzepakowska et al.[82]
	Pathological cause	Odontogenic infections and upper airway infections were the two most common causes of deep neck infections.	Huang et al.[66]
		The source of infection was the tonsil in 30 patients (40.5%), dental infection in 28 patients (37.8%) and salivary gland infection in 3 patients (4.1%). The aetiology was unknown in 11 cases (14.9%).	Hurley et al.[67]
		Only a few cases had a clear etiologic factor: three cases (9.68%) were of dental origin, two cases (6.45%) could be attributed to an ingested foreign body that had not been promptly recognised, and five cases (16.12%) were complications of peritonsillar infections.	Mayor et al.[73]
	Pre-disposing patient risk factors	The most prevalent comorbidities were cardio/pulmonary diseases (43.0%), diabetes mellitus (19.0%), nicotine consumption (16.0%) and intravenous drug injection (13.0%)	Kauffman et al.[8]
		Of the 131 patients, 59 (45.0%) had underlying systemic disease or were on immunosuppressive therapy.	Lee and Kanagalingam[13]
		Adjusted analysis from a multivariate regression showed that factors significantly associated with development of RPA in PTA patients included age groups of 40–64 years (odds ratio = 2.256; $p < .001$) and 65 and older (odds ratio = 2.086; $p = .045$).	Qureshi et al.[80]
Clinical Features		Signs and symptoms present were: neck swelling (94%), odynophagia/dysphagia (57%), trismus (57%) and dyspnoea (35%).	Garcia et al.[62]
		Symptoms at hospitalisation included pyrexia ($n = 8$), neck or mandibular swelling ($n = 5$), dyspnoea ($n = 4$), sore throat ($n = 4$) and dysphagia ($n = 2$).	Iwata et al.[68]
		The reasons for hospitalisation were: laterocervical or endopharyngeal infiltrative painful/painless swelling, sore throat, dysphagia, fever, neck pain, cervical erythema, endopharyngeal foreign body sensation, torticollis, trismus, fatigue, inspiratory type of respiratory distress and dysphonia.	Stan et al.[89]
Investigations		CT scans with contrast enhancement was performed on all patients to identify the sites and size of deep neck Space abscesses.	Lee and Kanagalingam[13]
		Laboratory assessments included routine measurements of ESR, WBC, and CRP. Clinical examinations included computed tomography (CT) to confirm the diagnosis.	Blochowiak et al.[54]
		Ninety-one (15.5%) had ultrasound scanning, 140 (23.9%) underwent CT and 4 (0.7%) underwent magnetic resonance imaging.	Mejzlik et al.[75]

(Continues)

TABLE 4 (Continued)

Themes	Subthemes	Quote	References
Management	Pre-hospital management	Twenty-four patients (32.4%) had visited their general practitioner (GP) or general dental practitioner (GDP) at least once and were discharged prior to appropriate referral to hospital. Of these patients, 17 (70.8%) received a course of antibiotics in the community before hospital admission.	Hurley et al.[67]
		Most cases had received some oral antibiotic and nonsteroid anti-inflammatory treatment elsewhere (24 cases; 77.42%).	Mayor et al.[73]
		Before admission, oral antibiotic therapy had been instituted by patient's general practitioners in 30 cases (68.2%) and oral steroids in 10 (22.7%).	Favaretto et al.[59]
	Airway management	Three patients had respiratory distress and required management of their airway by intubation in one case and a temporal tracheotomy in the other two.	Mayor et al.[73]
		Five were intubated but considered difficult cases by anaesthesiologists.	Suehara[97]
		All 19 patients who suffered upper airway obstruction either had a a tracheostomy or were intubated.	Lee and Kanagalingam[13]
	Surgical management	Two-hundred forty-six patients (93.50%) underwent surgery, including 237 (96.3%) patients who underwent incision and drainage. Reoperation was performed in 52 (19.8%) patients. In addition to primary incision and drainage, to eliminate infection source, tooth extraction and tonsillectomy were performed in 56 (22.80%) and 22 (8.90%) patients, respectively.	Adovica et al.[45]
		Six patients were treated with percutaneous needle aspiration, whereas two were taken to the operating room for intraoral incision and drainage.	Franzese and Isaacson[60]
		Fifty-three per cent of patients required an incision and drainage for definitive treatment of their DNSI, whereas 8.5% were treated with an ultrasound-guided needle aspiration.	Barber et al.[49]
	Non-surgical management	All patients were treated empirically with broad-spectrum intravenous antibiotics on admission.	Kauffman et al.[8]
		After surgical treatment, more than half of the patients received steroids (61%).	Tiefel et al.[92]
		Medical treatment was settled on the basis of cefotaxime plus metronidazole in 21 patients (67.74%); 7 cases (22.58%) were treated with clindamycin caused by allergy to beta-lactamics, and 3 cases (9.68%) were treated with amoxicillin/clavulanic acid. All cases were treated with methylprednisolone, and rehydration was used as required.	Mayor et al.[73]
	Length of stay	Mean duration of hospitalisation was 7.39 ± 4.21 days.	Riekert et al.[81]
		The hospital stay was a mean 8.2 ± 4.3 days (median 7.0 days).	Favaretto et al.[59]
		As expected, older age ($p = .002$), presence of diabetes ($p < .001$), readmission rates ($p = .013$) and repeat interventions ($p < .001$) were associated with longer LOS.	O'Brien et al.[77]
Complications		Thirty (11.40%) patients had complications, including airway obstruction ($n = 27$, 90%), mediastinitis ($n = 8$, 26.67%), pneumonia ($n = 4$, 13.33%), sepsis ($n = 3$, 10%), pleuritis ($n = 3$, 10%), facial nerve paresis ($n = 2$, 6.67%) and jugular vein thrombosis ($n = 1$, 3.33%). Only one patient, who developed jugular vein thrombosis, died.	Adovica et al.[45]
		Life-threatening complications affected a total of 60 patients (10.2%). Complications included dyspnoea ($n = 13$; 2.22%), sepsis ($n = 15$; 2.56%), mediastinitis ($n = 16$; 2.73%), pneumonia ($n = 7$; 1.19%), internal jugular vein thrombosis ($n = 4$, 0.68%), pleural effusion ($n = 2$; 0.34%) and death ($n = 3$; 0.51%).	Mejzlik et al.[75]
		Ten patients had complications. Mediastinitis was the most severe complication. Only one of five patients with mediastinitis survived.	Suehara[97]
Economic burden		The total cost of admission and treatment for all 74 patients was £421 795.89. The mean total cost per patient was £5699.94 (range: £332.06–£46 700.24).	Hurley et al.[67]
		Overall charges for PTA inpatient admissions with RPA accounted for approximately $40 million over the study period.	Qureshi et al.[80]
		In terms of staffing and instrumentation, grouped yearly costs for USD are estimated at 178.88/case. Actual mean costs per case were obtained for the surgical arm as follows: nursing staff, $122.60/case, other operating room staff, $81.22/case and instruments, $70.20/case, for a total of $192.83/case.	Biron et al.[53]

TABLE 4 (Continued)

Themes	Subthemes	Quote	References
Specialities involved in primary management		Twelve of these patients had their needle aspiration performed by an emergency department (ED) provider. Six required repeat intervention by an otolaryngologist (ENT) provider, giving ED providers a 50% success rate (6/12). Only one of the failures by needle aspiration was initially performed by an ENT provider, giving ENT providers a 97% success rate (1/32).	Tiefel et al.[92]
		Forty-four patients (59.5%) were admitted under the ENT team and 29 (39.2%) under the OMFS team. One patient (1.4%) was admitted under the rehabilitation medicine team because of a coexisting spinal injury.	Hurley et al.[67]
		As expected, the presence of diabetes ($p = .011$), increased repeat interventions ($p = .005$), and longer LOS ($p < .001$) were found in relation to treatment on a medicine service. Additionally, this confirmed that higher CCI ($p = .001$) and ASA ($p < .001$) were associated with treatment on a medicine service.	O'Brien et al.[77]

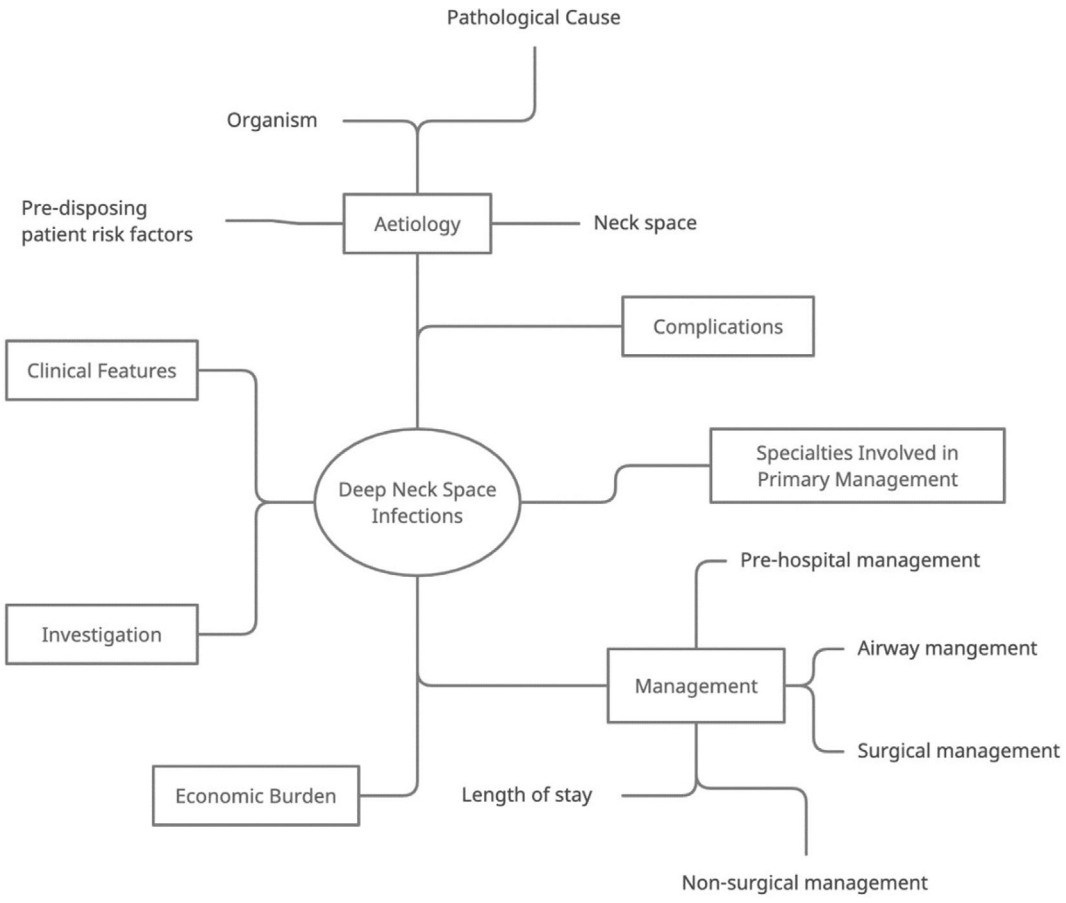

FIGURE 7 Qualitative thematic schema.

if the single RCT is excluded.[98] Even between the case series, there was no standardised reporting of parameters of studies investigating DNSIs and immense reporting differences existed. The nomenclature used across studies is inconsistent with certain studies reporting laryngeal abscesses with others reporting deep cervical. Some studies even include abscesses not in the neck, for example, retro-auricular or temporal. A number of studies reported single aetiology DNSIs, for example, six studies focussed on dental DNSIs. This exemplifies the intrinsically heterogeneous nature of DNSIs. Furthermore, certain studies focussed on a single modality of treatment, for example, radiologically guided aspiration. Both these factors increase heterogeneity and bias.

In addition, the chronological or geographical context of these studies is not considered. There will be a discrepancy in resources

available including access to both axial imaging and expertise in radiologically guided drainage. The disparity in resources available will also result in confounding.

There are no studies present that have recorded abscesses in all areas identified as deep neck spaces. The probable reason for the large volume of low-evidence studies is likely due to the nature of DNSIs themselves. They have high complication rate and a significant mortality rate as found in the included studies. Many case series have and continue to be accepted for publication and therefore continue to be present in literature often without any novel contribution.

One study that can explain this phenomenon is Djursic et al. 2017 which highlights several barriers to interventional studies in all medical fields[99]:

1. Inadequate funding
2. Overly complex regulations
3. Excessive monitoring
4. Restrictive privacy law and lack of transparency
5. Inadequate understanding of methodology

Although the above is specific to RCTs, it can be extrapolated to any interventional study and is relevant for studies investigating DNSIs.

3.3 | Limitations of review processes

The review process was limited by the type of data presented from included studies. Meta-analysis would not be possible. Therefore the results generated by this review will be evidence in keeping with the data presented. Inference of frequency of spaces involved has flaws because of publication bias.

Descriptive statistics and a systematic narrative synthesis rather than a traditional narrative review were undertaken. The qualitative facet of this review was included to provide a more meaningful insight into the literature as a large proportion of the data from included studies could not be synthesised due to their heterogeneity in their study design.

For the qualitative methodology, an inductive approach was chosen to generate the themes. The results of the qualitative analysis are generated in the form of codes. These codes showed a correlation between the qualitative and non-qualitative aspects of this systematic review. This aided in the enriching the narrative synthesis to help find meaning in the review's data.

3.4 | Implications for practice and future research

Considering all the results above, we propose that a *core outcome set*[100] be developed for all future studies that assess DNSIs. A consensus with stakeholder involvement should be used to inform the development of one; however, in the interim it should potentially include:

1. Demographics of patients
   - Age
   - Sex
   - Socioeconomic background
2. Co-morbidities
3. Aetiology of infection
4. Microbiology of infection
5. Imaging modalities used
   - Results of imaging modality including abscess size
6. Treatment antibiotic of choice
7. Treatment Interventions
8. Complications
9. Need for Re-intervention
10. Resolution

After a core outcome set is established, a second proposal should be a national collaborative cohort study assessing DNSIs, for example, with the use of a trainee collaborative.[101] With data finalised, a consensus study using the *Delphi Technique*[102] should be used to establish a treatment protocol for DNSIs.

4 | CONCLUSION

DNSIs comprise a selection of diseases. Research present on the subject is largely observational case series studies with globally high risk of bias and data synthesis as a result has been challenging. DNSIs have a significant burden of disease with high complication rates. Further research is required aligned with a core outcome measure and well-designed observational or interventional studies.

AUTHOR CONTRIBUTIONS

Zain Sheikh designed the work. Beverley Yu co-designed and acted as second reviewer. Emily Heywood and Natasha Quraishi extracted data and data analysis. Zain Sheikh undertook data analysis and write-up. Shahed Quraishi supervised with input.

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CONFLICT OF INTEREST STATEMENT

The authors declares that they have no conflict of interest.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ETHICS STATEMENT

No ethical approval was required for this project.

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