Fibrosarcomas of the Paranasal Sinuses: A Systematic Review

Moneb S. Bughrara 1, Tarek Almsaddi 2, Jithin John 2, Brandon Prentice 2, Jared Johnson 3, Oswaldo Henriquez 4, Adam J. Folbe 5

1. Internal Medicine, Oakland University William Beaumont School of Medicine, Rochester Hills, USA
2. Head and Neck Surgery, Wayne State University School of Medicine, Detroit, USA
3. Otolaryngology - Otolaryngology/Head and Neck Surgery, Wayne State University School of Medicine, Detroit, USA
4. Otolaryngology, Emory University, Atlanta, USA
5. Otolaryngology - Head and Neck Surgery, Beaumont Hospital, Royal Oak, USA

Corresponding author: Moneb S. Bughrara, mbuughara@oakland.edu

Abstract

Fibrosarcomas are rare, malignant neoplasms of mesenchymal origin. Fibrosarcomas appear to be sporadic, but cases of fibrosarcoma secondary to radiation of nasopharyngeal carcinomas have been reported. Paranasal sinus fibrosarcomas (PNFS) are even rarer with few cases being reported since the 1950s. There have been several retrospective cohort studies examining PNFS; however, to our knowledge, no comprehensive review exists. This review aims to summarize the findings of all published cases of PNFS from the 1950s to the 2020s. We hope that a comprehensive review will assist in accurate and early diagnoses of PNFS, and help guide treatment as early treatment is associated with a favorable prognosis. This systematic review reports results following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A search was conducted on PubMed, Embase, and Cochrane Library. Studies were screened using established inclusion/exclusion criteria. A total of 26 studies were included for data extraction, and relevant data were collected and analyzed. In our study, the most common study type was case reports (n = 19). The most common presentation for PNFS included male gender (n = 17) with maxillary sinus (n = 57) involvement. Patients commonly presented with complaints of nasal obstruction (n = 15), epistaxis (n = 11), and facial fullness/pain (n = 9). Surgical resection was the mainstay treatment, with the use of chemotherapy or radiation depending on surgical margins and resectability. The diagnosis was commonly made with histological analysis. This review of the literature provides a summary and reference of important presenting factors, elements of diagnosis, and treatment options regarding PNFS to help bring awareness and guide the treatment of such a rare disease. Moving forward, there is a greater need for larger standardized studies that can further complement our findings, as well as more consistent reporting of cases.

Introduction And Background

Fibrosarcomas are rare, malignant neoplasms of mesenchymal origin that comprise 7-10% of all head and neck sarcomas [1]. Fibrosarcoma appears to be sporadic, but cases of fibrosarcoma secondary to radiation of nasopharyngeal carcinomas have been reported [2]. Paranasal sinus fibrosarcomas (PNFS) are even rarer with few cases being reported since the 1950s. There have been several retrospective cohort studies examining PNFS; however, to our knowledge, no complete review exists [3,4].

As with other nasal cavity and paranasal sinus pathologies, PNFS often presents with unilateral nasal obstruction and epistaxis, sometimes being mistaken as a papilloma [1]. Previous reports have found associations with age and gender but reports vary [4,5]. Final staging and diagnosis are based on imaging, histopathology, and immunohistochemistry, with a characteristic herringbone arrangement of fibroblasts being pathognomonic [6].

PNFS is associated with a high risk of local recurrence and a low risk of distant metastasis [3]. Due to this association, PNFS are often treated with local excision with large margins with or without radiotherapy [1]. The extent of resection is also dependent upon the presence or absence of bone invasion. The anatomical site seems to correlate with the prognosis of sarcomas in general, with lesions of extremities having a more favorable outcome than central locations such as the pelvis, head/neck, and rib [2,7]. Prognosis according to paranasal sinus location has not been defined.

This review aims to summarize the findings of all published cases of PNFS from the 1950s to the 2020s. A total of 109 cases from 26 articles were collected from PubMed, Embase, and Cochrane. This review covers study characteristics, presentation of symptoms, location of the tumor, pathological findings, diagnosis, treatment, and complications. We hope that a comprehensive review will assist in accurate and early diagnoses of PNFS, as early treatment is associated with a favorable prognosis.
Methods

This systematic review reports results following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [8]. A search was conducted on PubMed, Embase, and Cochrane Library on September 25th, 2020 (Appendix). The objective of the study and inclusion/exclusion criteria were documented prior to initiating the study. Figure 1 demonstrates the search strategy for this review. All studies were assigned levels of evidence according to the Oxford Centre for Evidence-Based Medicine (OCEBM) [9].

Study Selection

Titles and abstracts of studies retrieved were screened for inclusion by two independent reviewers, and a separate third reviewer resolved all conflicts. The full text of included studies was subsequently reviewed. Studies were screened for inclusion using the Medical Subject Heading (MeSH) terms related to fibrosarcoma of the paranasal sinuses. Inclusion criteria included studies of patients with fibrosarcomas in the paranasal regions. Articles that were non-English, non-human studies, review articles, books, and studies unrelated to fibrosarcoma of the paranasal sinuses were excluded. Twenty-six studies were included for data extraction.

Data Extraction

Data extraction was conducted using a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA). Patient demographics were collected, such as age and gender. Study characteristics, including study type, year of publication, and authorship, and the number of patients in the study were collected. Clinical data
regarding presenting symptoms, location of the fibrosarcoma, use of chemotherapy and/or radiation, surgical interventions, and histopathology characteristics were gathered. Comments regarding patient outcomes were collected including survival and mortality. The collected data were then organized into graphical figures and tables.

**Results**

**General Overview**

A preliminary search yielded 632 articles after duplicates were removed, with 26 ultimately meeting inclusion criteria and were included in our study. No previous systematic reviews related to fibrosarcomas of the paranasal sinuses were identified. Articles ranged in publication date from 1952 to 2019. A total of 109 patients were derived from 19 case reports, four case series, and three retrospective cohort studies. All included studies are listed in Table 1.

| Title                                                      | Author                                           | Year | Study type | Level of evidence | No. of patients |
|------------------------------------------------------------|--------------------------------------------------|------|------------|-------------------|-----------------|
| A case of fibrosarcoma of the ethmoid                      | Stratton [10]                                   | 1953 | Case report | IV                | 1               |
| Fibrosarcoma of the ethmoid                                | Prasad and Kanjilal [11]                         | 1969 | Case report | IV                | 1               |
| Fibrosarcoma of the nose and paranasal sinuses             | Richardson and Maguda [12]                      | 1970 | Case report | IV                | 2               |
| Fibrosarcoma of nose and paranasal sinuses                 | Agarwal et al. [13]                             | 1980 | Case series | IV                | 2               |
| Fibrosarcomas of the nose and paranasal sinuses            | Broniatowski and Haria [14]                     | 1981 | Case report | IV                | 2               |
| Fibrosarcoma of the maxillary sinus                        | Oppenheimer and Friedman [15]                   | 1988 | Case report | IV                | 1               |
| Fibrosarcoma of the ethmoid                                | Smith and Soames [16]                           | 1989 | Case report | IV                | 1               |
| Fibrosarcoma of the nose and the paranasal sinuses         | Olekszyk et al. [17]                            | 1989 | Case report | IV                | 1               |
| Fibrosarcoma arising in the maxillary sinus: CT and MR features | O’Connell et al. [18]                           | 1996 | Case report | IV                | 1               |
| Inverted papilloma-like sinonasal epithelial hyperplasia, overshadowing underlying sinonasal fibrosarcoma: a diagnostic pitfall | Maly et al. [19]                               | 2006 | Case report | IV                | 1               |
| Fibrosarcoma of the maxillary sinus                        | Mansouri et al. [20]                            | 2006 | Case report | IV                | 1               |
| Sinonasal fibrosarcoma: a case report                      | Plaza et al. [21]                               | 2006 | Case report | IV                | 1               |
| Unusual synchronous presentation of maxillary sinus fibrosarcoma and gemistocytic astrocytoma with a complication called leukocytoclastic vasculitis: a case report | Cadir et al. [22]                              | 2009 | Case report | IV                | 1               |
| A rare sinonasal neoplasm: fibrosarcoma                    | Bercin et al. [23]                              | 2011 | Case report | IV                | 1               |
| Infantile fibrosarcoma of the maxillary sinus: significant response | Palacios and Lam [24]                          | 2012 | Case report | IV                | 1               |
| Infantile fibrosarcoma of ethmoid sinus, misdiagnosed as an adenoid in a 5-year-old child | Geramizadeh et al. [25]                        | 2015 | Case report | IV                | 1               |
| Destructive fibrosarcoma of the maxillary sinus            | Ekinci et al. [1]                               | 2018 | Case report | IV                | 1               |
| Recurrent fibrosarcoma of maxillary sinus involving the cranial base: a rare case | Jin et al. [8]                                 | 2018 | Case report | IV                | 1               |
| Zouhair et al.                                              |                                                  |      |            |                   |                 |
| Fibrosarcoma of the ethmoid sinus: a rare entity | [26] | 2019 | Case report | IV | 1 |
|---|---|---|---|---|---|
| Chart review | | | | | |
| Fibrosarcoma of the paranasal sinuses | Cronin [27] | 1973 | Case series | IV | 3 |
| Unusual malignant tumours of the maxillary sinuses | Wolfowitx and Schmaman [28] | 1975 | Case series | IV | 1 |
| Fibrosarcoma of the nose and paranasal sinuses | Rockley and Liu [29] | 1986 | Case series | IV | 9 |
| Sarcomas of nasal cavity and paranasal sinuses: chondrosarcoma, osteosarcoma and fibrosarcoma | Koka et al. [30] | 1994 | Retrospective cohort | IIB | 14 |
| Malignant tumors of the sinonasal tract in the pediatric population | Yi et al. [31] | 2012 | Retrospective cohort | IIB | 2 |
| Sinonasal fibrosarcoma: analysis of the Surveillance, Epidemiology, and End Results database | Patel et al. [3] | 2015 | Retrospective cohort | IIB | 51 |
| Fibrosarcoma arising in the paranasal sinus: a clinicopathological and radiological analysis | Zeng et al. [5] | 2018 | Case series | IV | 7 |

### TABLE 1: Characterization and study type of published fibrosarcoma literature

**Clinical Characteristics Analysis**

The described data for clinical characteristics can be found in Table 2. In total, 26 studies were used for the analysis of clinical characteristics. Out of 26 studies, nasal obstruction (n = 15) was noted to be the most common presenting symptom, followed by epistaxis (n = 11), facial fullness/pain (n = 9), exophthalmia (n = 4), anosmia (n = 4), headache (n = 2), rhinorrhea (n = 1), diplopia (n = 1), hypoesthesia (n = 1), dyspnea (n = 1), snoring (n = 1), decreased appetite (n = 1), fever (n = 1), drowsiness (n = 1), palatal discomfort (n = 1), loosening of teeth (n = 1), incontinence (n = 1), confusion (n = 1), proptosis (n = 1), and palpebral edema (n = 1). This information is also graphically depicted in Figure 2. Out of 26 studies, the maxillary sinus was the most common location for fibrosarcoma (n = 57), followed by the ethmoid sinus (n = 18), frontal sinus (n = 5), and sphenoid sinus (n = 5). Information regarding location is also represented in Figure 3. The provided histological information is also noted in Table 2.
| Authors                  | Year | Age | Gender | Symptoms                                                        | Site | Histology                                                                 |
|--------------------------|------|-----|--------|-----------------------------------------------------------------|------|---------------------------------------------------------------------------|
| Mansouri et al. [20]     | 2006 | 16  | Male   | Obstruction, left-sided anosmia, intermittent paranasal sinus    | Left | Maxillary Elongated spindle cells arranged in bundles                  |
|                          |      |     |        | drainage, and intact left facial nerve                           |      |                                                                           |
| O'Connell et al. [18]   | 1996 | 36  | Female | Facial fullness/pain, epistaxis, nasal obstruction, and exophthalmia | Right| Ethmoid and maxillary Inter-weaving bundles of spindle-shaped cells were noted. Positive for vimentin |
| Palacios and Lam [24]   | 2012 | 2.8 | Female | Not described due to the patient's age                          | Right| Maxillary Not described                                                  |
| Plaza et al. [21]       | 2006 | 58  | Male   | Epistaxis, nasal obstruction, exophthalmia, hyposmia, and frequent sinus cephalalgias. A physical exam revealed palpebral hematoma, left proptosis, and orbital cellulitis | Not described | Ethmoid Composed of elongated spindle-shaped cells arranged in a herringbone pattern |
| Stratton [10]           | 1953 | 56  | Male   | Facial fullness, nasal obstruction, drowsiness, pyrexia, bilateral pain sinusitis, headaches, and occasional incontinence | Right| Ethmoid with metastasis to the antrum, ethmoidal sphenoidal sinus, and the floor of the frontal sinus The tissue was found to be spindle cell-like |
| Smith and Soames [16]   | 1989 | 24  | Male   | Epistaxis and anosmia                                           | Left | Ethmoid Cellular spindle cell tumor with varying amounts of the intercellular collagenous stroma |
| Agarwal et al. [13]     | 1980 | 42, 45 | Female, male | Epistaxis and nasal obstruction                                    | Left | Maxillary Malignant cells running in various planes were described, in a crisscross pattern. Nuclei were elongated |
| Broniatowski and Haria [14] | 1981 | 47, 68 | Male, male | Epistaxis and nasal obstruction                                    | Left | Maxillary Composed of irregularly arranged, moderately pleomorphic oval cells with an interlacing pattern |
| Olekszyk et al. [17]    | 1989 | 73  | Female | Nasal obstruction                                               | Right| Ethmoid, maxillary, and sphenoid Spindled neoplastic cells with an island of bone and respiratory tract epithelium with an underlying spindled neoplasm |
| Oppenheimer and Friedman [15] | 1988 | 29  | Male   | Facial fullness/pain, sinusitis, and tenderness over the right maxilla | Right| Maxillary and sphenoid Not described                                      |
| Prasad and Kanjilal [11] | 1969 | 8   | Male   | Nasal obstruction                                               | Left | Ethmoid The tumor consists of interfacing sheets of spindle-shaped cells with pleomorphic large irregular hyperchromatic nuclei |
| Zeng et al. [5]         | 2018 | 22, 41, 48, 25, 50 | Female, female, female, female | Facial fullness/pain, epistaxis, and nasal obstruction | Right | maxillary sinus (x4), left maxillary sinus(x2), Maxillary (x6), ethmoid (x1) 5 well-defined and 2 ill-defined tumors. low-grade (n = 3), intermediate grade (n... |
| Study                | Year | Gender | Symptoms                                      | Laterality | Location of Sinus                      | Histological Remarks                          |
|----------------------|------|--------|-----------------------------------------------|------------|----------------------------------------|-----------------------------------------------|
| Yi et al. [31]       | 2012 | 43, 73 | Male, male                                   | Not described | Not described                          | Ethmoid sinus (x1), Maxillary sinus (x2), ethmoid (x1), high grade (n = 3) |
| Patel et al. [3]     | 2015 | N/A    | N/A                                          | Not described | Not described                          | Maxillary (x26), ethmoid (x6), frontal (x2), sphenoid (x2) |
| Wolfowitx and Schmaman [28] | 1975 | 23     | Female                                       | Left       | Ethmoid and maxillary                  | Not described                                 |
| Cronin [27]          | 1973 | 2, 33, 55 | Female, female, male                        | Left       | Frontal                               | Long spindle-shaped cells loosely arranged in a non-staining matrix |
| Rockley and Liu [29] | 1986 | N/A    | N/A                                          | Not provided | Not described                          | Fronto-ethmoid (x1), maxillary (x8) |
| Bercin et al. [23]   | 2011 | Female | Epistaxis, nasal obstruction, diplopia, proptosis, hyposmia, headaches, and palpebral edema | Bilateral | Ethmoid, frontal                      | Weakly positive for CD34 and SMA |

**TABLE 2: Overview of age, gender, symptoms, laterality, location of sinus, and histological remarks**

SMA: smooth muscle actin.

**FIGURE 2: Presenting symptoms**
The aggregate data for treatment and outcome of patients with fibrosarcoma can be found in Table 3. There were 109 patient cases that were analyzed in regards to the type of treatment they received. In total, 46% (n = 49) of patients underwent only surgical management. In total, 39% (n = 41) of patients received radiation as a form of treatment, 10% (n = 11) of patients underwent chemotherapy and no radiation, and 5% (n = 5) of patients received both chemotherapy and radiation. Out of 52 patient cases that reported mortality information within one year of treatment, 35% (n = 18) of cases reported patient death within one year. The individual surgical approaches are described in Table 3.

| Author          | Year | Chemotherapy or radiation                  | Surgical remarks                                                                 | Patient outcome remarks                                                                 | Reported mortality and survival                              |
|-----------------|------|---------------------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------|
| Stratton [10]   | 1953 | The patient received chemotherapy and radiation | Surgical summary: malignant structures were removed from the antrum, ethmoids, sphenoid, and the frontal sinus as tumors were also found there | The patient tolerated the surgery well, with occasional complaints of headaches        | Still alive at 6-year follow-up                             |
| Prasad and Kanjilal [11] | 1969 | The patient received radiation               | Surgical summary: malignant structures were removed through the mouth and nose under general anesthesia | The patient tolerated the surgery well and did not complain of any symptoms. Radiological images showed normal air shadows, indicating nasal and sinus cavities were clear of obvious malignancy | N/A                                                         |
| Richardson and Maguda [12] | 1970 | 1 patient case received radiation and 1 patient case did not receive chemotherapy or radiation | Surgical summary: Case 1 - ethmoidectomy was performed. Case 2 - the patient was advised to have a radical resection of the left antrum, ethmoids, and orbital exenteration. However, the patient refused orbital surgery, so only a partial left maxillectomy was done | Case 1 - the patient died 4 years after the initial diagnosis due to hemorrhage from fibrosarcoma, with local extension into the paranasal sinuses. Case 2 - tolerated surgery well without evidence of local recurrence or metastasis | Case 1 - died 4 years after initial presentation. Case 2 - was still alive at 10 months follow-up |
| Author(s)                        | Year | Intervention Details                                                                                                                                                                                                 | Surgical Details                                                                 | Outcome Notes                                                                                   |
|--------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Wolfowitx and Schmaman         | 1975 | High-grade tumor, the patient received palliative radiotherapy                                                                                                                                                    | No surgical intervention was done                                                | Died 3 weeks after admission                                                                 |
| Agarwal et al.                 | 1980 | The patient received radiotherapy                                                                                                                                                                                   | Surgical summary: using a Caldwell-Luc approach, resection of the tumor was done | Case 1 - the patient is still alive 5 years after the initial visit. Case 2 - the patient is still alive 4 years after the initial visit |
| Broniatowski and Haria         | 1981 | 1 patient case received chemotherapy and radiation and 1 patient case did not receive chemotherapy or radiation                                                                                               | Surgical summary: left radical maxillectomy with ethmoidectomy, sphenoidotomy, and exenteration of the orbit was performed | Case 1 - died 6 months after surgery from disseminated disease. Case 2 - developed local palatal recurrence, which was treated by wide excision. The patient died two weeks later from widespread disease |
| Rockley and Liu                | 1986 | 1 patient case received chemotherapy and radiation after surgery; 2 patient cases received radical radiation after surgery                                                                                      | Surgical summary: 7 patient cases received surgical excision as primary treatment | Case 1 - died after 1.6 years. Case 2 - died after 1 years. Case 3 - died after ½ years. Case 4 - died after 2 years (L). Case 5 - died 1.7 years later. Case 6 - alive after 14 years. Case 7 - died after 11 months. Case 8 - died after 4 months. Case 9 - died after 4 years. Case 10 - alive after 9 years |
| Oppenheimer and Friedman       | 1988 | The patient received radiation                                                                                                                                                                                     | Surgical summary: radical maxillectomy and orbital exenteration                    | Died 9 months after the initial visit                                                                 |
| Smith and Soames               | 1989 | The patient did not receive chemotherapy or radiation                                                                                                                                                            | Surgical summary: the eye was removed en bloc with the left ethmoidectomy, with partial maxillectomy and removal of the cribriform plate and surrounding bone | Still alive at 5-year follow-up |
| Olekszyk et al.                | 1989 | The patient received radiation                                                                                                                                                                                     | Surgical summary: the patient received maxillectomy and ethmoidectomy             | N/A                                                                                          |
| Koka et al.                    | 1994 | 7 patients received chemotherapy and 11 patients received radiation                                                                                                                                               | Not described                                                                    | Survival at 5 years was 21% of patients. Fibrosarcoma was 78% at 1 year, 2 years was 42%, 28% at 3, and 21% at 5 years. Female patients had a slightly better survival rate |
| O'Connell et al.               | 1996 | The patient received both chemotherapy and radiation                                                                                                                                                              | Not described                                                                    | Six weeks post-chemoradiation therapy, CT showed continued growth of the lesion, extending to the intracranial region |
| Maly et al.                    | 2006 | The patient did not receive chemotherapy or radiation                                                                                                                                                            | Surgical summary: medial maxillectomy with excision of the tumor                  | Patient outcome not provided                                                                 |

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| Study                        | Year | Treatment                                                                 | Surgical Summary                                                                                                                                  | Outcome                                                                 |
|-----------------------------|------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| Mansouri et al. [20]        | 2006 | The patient received chemotherapy and radiation                           | Surgical summary: left medial maxillectomy was done                                                                                             | Died 2 years after the initial visit                                  |
| Plaza et al. [21]           | 2006 | The patient did not receive chemotherapy or radiation                      | Surgical summary: complete removal of the neoplasia was achieved via an endoscopic approach                                                   | Died 2 years after the initial visit due to another primary cancer    |
| Cadir et al. [22]           | 2009 | The patient received radiation                                            | The patient had a partial maxillectomy with orbital reconstruction                                                                          | Died 2.5 years after the initial visit                                 |
| Yi et al. [31]              | 2012 | Both patients received chemotherapy                                       | Surgical summary: Case 1 had a wide excision of the tumor. Case 2 had excision of the tumor via open rhinoplasty approach                     | Case 1 - alive at 10.4-year follow-up. Case 2 - Alive at 5.7-year follow-up |
| Palacios and Lam [24]       | 2012 | The patient received chemotherapy                                         | Surgical summary: anterior ethmoidectomy was performed with drainage of purulent material                                                  | Alive at 3-year follow-up                                            |
| Geramizadeh et al. [25]     | 2015 | The patient did not receive chemotherapy or radiation                      | Surgical summary: anterior ethmoidectomy was performed with drainage of purulent material                                                  | Alive at 6-month follow-up                                           |
| Patel et al. [3]            | 2015 | Out of 51 patients, 30 patient cases received only surgery, 3 patient cases only received radiotherapy, and 16 patient cases received surgery and radiotherapy | Not described                                                                                                                                  | 57.7% overall survival of maxillary sinus cases                       |
| Ekinci et al. [1]           | 2017 | The patient received radiation                                            | Surgical summary: total excision with the Denker approach was completed. Inferior and medial conchas were excised and medial maxillectomy was performed | N/A                                                                   |
| Zeng et al. [5]             | 2018 | 2 patient cases received radiation                                        | Surgical summary: radical surgical resection was done in all seven patients, including total maxillectomy (n = 6) and lateral rhinotomy (n = 1) | Case 1 - 5.5 years later alive but with progressive disease. Case 2 - 3.25 years later dead. Case 3 - 5.4 years later alive. Case 4 - 3.1 years later alive. Case 5 - 4.8 years later alive. Case 6 - 1.2 years later death |
The patient received chemotherapy. Surgical summary: total right maxillectomy was performed. The tumor was excised along with the infiltrated right masseter, as well as the medial and lateral pterygoids. Patient experienced recurrence of tumor after 5 months. N/A

The patient did not receive chemotherapy or radiation. Surgical summary: total excision of the tumor was performed endoscopically. The patient tolerated the procedure well. No residual tumor cells were found after one year of follow-up. N/A

The patient did not receive chemotherapy or radiation. Surgical summary: Lynch incision was performed to remove the tumor because the frontal sinus was already eroded. The patient tolerated the procedure well. There was no sign of recurrence during 2-year follow-up. Still alive at 2-year follow-up

**TABLE 3: Treatment methods and outcomes**

**Discussion**

To the best of our knowledge, no comprehensive review of PNFS exists. Consequently, a consensus on PNFS demographics, presentation, diagnosis, treatment, and prognosis has not been found. This is significant because only a few cases of PNFS have been reported since the 1950s and an early diagnosis is associated with a more favorable outcome. We include our recommendations below.

**Demographics and Symptoms**

Cancer of the paranasal sinuses is a rare condition alone, with one case occurring in every 100,000 people. Studies have shown that paranasal sinus tumors tend to occur at an average age between 50 and 60 years [32]. Paranasal sinus cancers from 1999 to 2007 were seen to occur twice as high in males than females [33], while we saw an equal representation of female and male presentations for fibrosarcomas of the paranasal sinuses. Our review found that the most common site for fibrosarcoma of the sinuses was the maxillary sinus, which could be due to the fact that the maxillary sinus is the largest paranasal sinus.

In our review, the most common presenting symptom was nasal obstruction followed by epistaxis and facial fullness/pain. These symptoms are consistent with other cancers of the paranasal sinus. These presenting symptoms are common with many other conditions and can oftentimes be overlooked. The presence of unilateral symptoms that do not improve with treatment should raise the suspicion of a possible mass such as a fibrosarcoma and should warrant further workup [33].

**Diagnostic Methods**

In routine clinical practice, paranasal fibrosarcoma is commonly misdiagnosed as other neoplasms due to its rarity and non-specific symptomatology. Therefore, it is critical to be familiar with the imaging features that differentiate paranasal fibrosarcoma from other malignancies [5]. Additionally, the rarity of the disease and the relatively few studies within the literature examining the imaging characteristics of PNFS continue to make the preoperative diagnosis of PNFS a challenge [5]. It is also critical that physicians be aware of the advantages and disadvantages of the different imaging modalities. The most common diagnostic method to evaluate a mass of the paranasal sinus area is nasal endoscopy [31]. Histology can additionally aid in further diagnosis. Histological characteristics for fibrosarcoma tend to be consistent with spindle cells that are often arranged in a herringbone pattern with staining for CD34 and vimentin [34], which was seen across many of our cases as seen in Table 2.

When suspecting PNFS, there are particular findings found on certain modalities that may rule in or out other diagnoses on the differential [35]. One study identified the common CT and MRI features seen in patients with confirmed PNFS [5]. This particular study confirmed that PNFS commonly presents as a solitary lobulated or irregular heterogeneous mass, with either well- or ill-defined margins. Furthermore, there should be increased suspicion of PNFS when the well- or ill-defined paranasal neoplasm appears mildly hypointense on T2-weighted MRI that also shows bone destruction and a heterogeneous delayed contrast enhancement pattern [5]. These common features of PNFS emphasize the importance of radiographic findings to arrive at the diagnosis of this already rare and complex disease process.

**Treatment and Mortality**

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An accepted mainstay treatment of fibrosarcoma of the sinuses currently does not exist. It is important to recognize that local recurrence is common for PNFS, and distant metastasis rarely occurs as well. According to analyzed studies, the most commonly used type of treatment was surgical management, as shown in Table 3. This could be due to the local destructive feature of fibrosarcomas as opposed to a metastatic nature [22]. Some studies suggest radiotherapy along with surgical management improves survival rates [23]. While other studies recommend surgery as the mainstay of treatment, with radiotherapy for more malignant tumors, as reflected by the results of this study [23,26]. Due to the frequent local recurrent nature of fibrosarcomas, some studies recommended a wide local excision with an extensive surgical border [1,14,22].

It is also worth mentioning the use of endoscopic surgery as opposed to open surgeries. While some studies suggest the use of endoscopic surgeries due to the decreased surgical complications and length of stay, other studies disapprove of the use of endoscopic surgeries due to the extensive regional nature of the tumor.

Additional research is required to give a definitive statement on indications and contraindications in the use of endoscopic surgeries in fibrosarcoma removal. According to the analyzed studies, it is suggested that surgeons are opting to mainly treat with surgical management as opposed to a multimodal type of management. We recommend that surgeons approach fibrosarcomas with local excision and large surgical border, followed by chemotherapy and radiotherapy, especially if the tumor cannot be fully removed or if surgical border involvement on pathology report is revealed. In addition, for tumors that are unresectable, it is suggested that preoperative chemotherapy should be used to decrease tumor size followed by resection.

Our results suggest that PNFS is associated with a high rate of mortality, with death occurring within one year of treatment in 35% (n = 18) of cases. However, mortality information was only available for 47% (n = 52) of patient cases. Studies that include long-term patient outcomes are needed to better assess PNFS prognosis. Published data have suggested that prognosis is associated with the degree of histological differentiation [18]. Similarly, additional studies on the rate of PNFS reoccurrence are needed. Past reviews have suggested a high rate of PNFS reoccurrence, but the studies in this review did not include sufficient prognostic data [3]. Once these data are included, conclusions on which treatments are associated with favorable outcomes can be made.

Limitations
There are several notable limitations worth mentioning. Since there were no prospective studies found, all data are based on retrospective research. Additionally, the majority of studies were case studies and series, and there were no randomized controlled trials comparing various treatment approaches, making it difficult to compare the efficacies of treatment approaches. The use of solely one primary treatment was not explicitly in the articles, which may skew the results. The mortality data were gathered from sources that mentioned any mortality information within the article. Since timeframes varied greatly for reporting the death and postoperative prognosis of patients, the mortality results may be skewed. Furthermore, the reporting of larger studies oftentimes grouped varying tumors as well as locations other than the paranasal sinuses in analysis, making some data difficult to extract. Across studies, there was not a uniform way in which data were presented, causing some information to be unavailable. To address these limitations, it would be important for larger and more standardized studies to further support our findings. Furthermore, more consistent reporting of patient progress following treatment will help with the assessment of optimal treatment options.

Conclusions
Fibrosarcoma of the paranasal sinuses is a rare but dangerous disease. By conducting this study, we aim to provide physicians with a comprehensive review to assist in the management of PNFS. Physicians should maintain a high index of suspicion when presented with a patient with non-specific symptoms, such as nasal obstruction and facial fullness and pain, which are unresolved. Nasal endoscopy can be utilized to visualize the mass, and the use of CT and MRI can aid in further diagnosis. Ultimately, histology can confirm the final diagnosis. The mainstay of treatment is surgical excision with the use of radiation or chemotherapy depending on resectability and surgical borders. With a high rate of mortality, early identification and treatment are essential.

Appendices
Search terms
Embase search: (fibrosarcoma/EXP OR fibrosarcoma OR fibroblastic sarcoma/EXP OR Fibroblastic sarcoma/EXP OR (fibroblastic AND (sarcoma/EXP OR sarcoma))) AND ((sinus/EXP OR sinus OR paranasal OR maxillar/EXP OR maxillary OR frontal OR ethmoid OR ’sphenoid’/EXP OR sphenoid)).

PubMed and Cochrane search: (fibrosarcoma OR fibroblastic sarcoma) AND (sinus OR paranasal OR maxillary OR frontal OR ethmoid OR sphenoid).

Additional Information
Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: Payment/services info: All authors have declared that no financial support was received from any organization for the submitted work. Financial relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. Other relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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