Int. J. Radiation Oncology Biol. Phys., Vol. 14, pp. 11–22
Printed in the U.S.A.

0360-3016/88 $3.00 + .00

● *Original Contribution*

MALIGNANT TUMORS OF THE NASAL CAVITY AND ETHMOID AND SPHENOID SINUSES

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Between October 1964 and December 1983, 48 patients with malignant tumors of the nasal cavity (31), ethmoid sinus (13), or sphenoid sinus (4) were treated with curative intent by radiation therapy. There were 21 squamous cell carcinomas, 14 minor salivary gland tumors (adenocarcinoma, adenoid cystic carcinoma, and mucoepidermoid carcinoma), 3 malignant melanomas, 2 soft tissue sarcomas, and 8 esthesioneuroblastomas. Forty-two patients were treated with irradiation alone and six with planned combined irradiation and surgery. The 10-year actuarial local control rate for Stage I (limited to site of origin; 7 patients) was 100%; for Stage II (extension to adjacent sites, e.g., adjacent sinuses, orbit, pterygomaxillary fossa, nasopharynx; 19 patients) was 53%; and for Stage III (destruction of skull base or pterygoid plates, or intracranial extension; 22 patients) was 30%. Of 24 failures at the primary site, 10 occurred >24 months after completion of irradiation. With the exception of adenoid cystic carcinoma (17% local control at 15 years), the ultimate local control rates for all histologies were in the range of 40% to 60%. Of 7 patients with documented intracranial extension, 3 (43%) remained free from local recurrence 3.5, 4, and 9 years after treatment. The 5-, 10-, 15-, and 20-year uncorrected actuarial survival rates for all 48 patients were 52%, 30%, 22%, and 22%, respectively. Continuous disease-free survival according to stage at 10 years was 86% for Stage I, 42% for Stage II, and 22% for Stage III. The single failure in a patient with Stage I disease was a lymph node metastasis that was successfully managed by radical neck dissection. The orbit was grossly invaded by tumor prior to treatment in 22 patients (46%). Sixteen (33%) of 48 patients developed unilateral blindness secondary to radiation retinopathy or optic neuropathy; in the majority of these patients the complication was anticipated because the ipsilateral eye was irradiated to a high dose. Four patients (8%) unexpectedly developed bilateral blindness 17, 35, 46, and 90 months following treatment owing to optic nerve injury. A discussion of possible means of avoiding this latter, unacceptable complication is included.

Malignant neoplasms of nasal cavity, Malignant neoplasms of paranasal sinuses (ethmoid and sphenoid), Local control, Survival, Complications of treatment.

INTRODUCTION

Primary malignant tumors of the nasal cavity and paranasal sinuses are rare, with most reported series composed largely of lesions arising from the maxillary antrum. There are few reported results of treatment of primary lesions of the nasal cavity and ethmoid/sphenoid complex.[4,34] Prolonged follow-up is necessary because primary or metastatic failures or death from several of the common histologic types of tumors occurring in this area (e.g., adenoid cystic carcinoma, adenocarcinoma, and esthesioneuroblastoma) may occur 5 or more years after treatment.[1,10,13,15,19,22,28,31,35] Local recurrence of squamous cell carcinoma of the ethmoid sinus is not rare between 2 and 5 years posttreatment[17]; such late recurrence is unusual for squamous cell carcinoma at other head and neck sites. Most patients with mucosal malignant melanoma who live for 5 years after treatment also eventually succumb to their disease.[12,14,16,32]

Because of their proximity to the skull base, central nervous system, and orbit, these lesions cause considerable technical difficulty for both surgeon and radiotherapist. Operation often requires a combined transcranial, transfacial approach; although the risk of complications has been greatly reduced by improved operative techniques and perioperative care,[30] those complications that

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Presented at the 5th Annual Meeting of the European Society for Therapeutic Radiology and Oncology, Sept. 8–10, 1986, Baden-Baden, West Germany.

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Accepted for publication 28 July 1987.

do occur are often life-threatening, and most series report an operative mortality rate of approximately 5%.[5,9,18,36,38] Many other patients are excluded from treatment by operation because they have lesions involving areas (e.g., sphenoid sinus, nasopharynx, middle cranial fossa, complete destruction of pterygoid plates) that make surgical cure unlikely. Eye complications are the most frequent and devastating complications of radiation therapy. Although many of these patients would require unilateral orbital exenteration if treated by surgery, radiation therapy has the disadvantage of irradiating the optic nerves bilaterally so that patients are exposed to some risk of bilateral blindness.[25,34] Although brain necrosis can occur, it is rare.[2]

This is a report of the 19-year experience of the University of Florida Division of Radiation Therapy with malignant tumors of the soft tissues of the nasal cavity and ethmoid or sphenoid sinuses.

METHODS AND MATERIALS

Patient characteristics

Between October 1964 and December 1983, 52 patients with a variety of malignant tumors of the soft tissues of the nasal cavity (excluding the nasal vestibule) and ethmoid or sphenoid sinuses received radiation therapy at the University of Florida Division of Radiation Therapy. Lymphomas, plasmacytomas, and primary tumors of bone were excluded. Two of the patients (1 with distant metastases at diagnosis and 1 with chronic dementia and multiple medical problems) received only palliative treatment and will not be discussed. Two other patients in whom irradiation was initiated but not completed due to patient refusal are likewise excluded. Forty-eight patients were treated with curative intent. None were lost to follow-up. Six of the 48 patients were irradiated for postsurgical recurrence; none of the 48 patients had received prior irradiation.

Forty-two patients (37 with *de novo* lesions and 5 with postsurgical recurrences) were treated with radical courses of irradiation alone. Six patients (5 with *de novo* lesions and 1 with postsurgical recurrence) received planned combined irradiation and surgery (2 preoperative irradiation, 4 postoperative irradiation).

The distribution of patients according to histologic type and primary site is shown in Table 1. While it is relatively easy to determine the site of origin of early cancers, advanced tumors involving more than one anatomic area cause some difficulty; in such instances, the primary site was usually assigned to the location harboring the greatest volume of tumor, taking into account early symptomatology and known spread patterns.

In the early years, disease extent was assessed by conventional sinus films and pluridirectional tomography in the anteroposterior (AP), lateral, and sometimes basal projections. When suspected, evidence for intracranial extension was sought by angiogram, brain scan, and occasionally electroencephalogram. In later years, computed tomography (CT) replaced most of the above studies. Magnetic resonance imaging (MRI) was not available during the study period. For the past 10 years, examination and photography of lesions of the nasopharynx and nasal cavity has been greatly facilitated by rigid and flexible fiberoptic telescopes.[20]

Table 1. Patient distribution according to primary site and histology (48 patients)

Histology	Nasal cavity	Ethmoid sinus	Sphenoid sinus
Squamous cell carcinoma	10	9	2
Minor salivary gland			
Adenocarcinoma	4	2	1
Adenoid cystic carcinoma	3	2	1
Mucoepidermoid carcinoma	1	0	0
Esthesioneuroblastoma	8	0	0
Sarcomas	2	0	0
Malignant melanoma	3	0	0

There is no widely accepted staging system for tumors of the nasal cavity and ethmoid/sphenoid sinuses. In the present analysis, patients were grouped retrospectively into the following stages based on prognostic factors that seemed to correlate best with response to treatment: Stage I, limited to site of origin; Stage II, extension to adjacent sites (e.g., orbit, nasopharynx, paranasal sinuses, skin, pterygomaxillary fossa); Stage III, base of skull or pterygoid plate destruction and/or intracranial extension.

The distribution of patients according to stage and the primary site is shown in Table 2. Forty-six percent (22/48) of the patients had Stage III disease at presentation. All 7 Stage I lesions arose from the nasal cavity, which is compatible with the fact that these lesions produce earlier symptoms than lesions in the other primary sites. Sphenoid sinus cancers were not detected until far advanced; severe headache, cranial nerve palsies, and long delays in establishing a correct diagnosis were routine in our 4 patients, all of whom had Stage III disease at diagnosis.

Because of these tumors' proximity to the orbit, ophthalmic complaints were frequent and, at times, the only early symptom. Of 48 patients, 10 (21%) presented with advanced orbital invasion (exophthalmos, blindness, or

Table 2. Distribution according to stage and primary site (48 patients)

Stage	Nasal cavity	Ethmoid sinus	Sphenoid sinus
I	7	0	0
II	11	8	0
III	13	5	4
Total	31	13	4

a palpable orbital mass) and 12 others (25%) had radiographic evidence of orbital extension but no findings on physical examination.

The mean age was 59 years (range 14–85). Males made up 69% of the group; 94% were white.

Anatomic relationships pertinent to radiation treatment planning

Eye and optic nerve. Unsuspected tumor extension into the orbit may result in treatment failure following either radiation therapy[4,8,29] or surgery.[18] The orbits are conical in shape; when viewed in a straight anteroposterior projection, the floor of orbit rises above the level of the orbital rim as palpated anteriorly. The lateral walls of the ethmoid sinuses are parallel in their upper portions, but posteriorly and inferiorly the walls diverge laterally to form the medial floor of the orbit. Too tight treatment planning will result in a geographic miss.

When it is necessary to treat a portion of the orbit, the patient is usually instructed to keep his eyes open and gaze straight ahead; lateral or upward gaze often rotates more of the posterior pole of the eye into the high-dose field. The accessory lacrimal glands, which are responsible for the basal flow of tears, are most plentiful in the upper eyelid. Cephalad displacement of the upper lid with a retractor often enables sparing of some of these glands, as well as the major lacrimal gland if the superolateral orbit can be shielded.

In the cephalocaudad dimension, the optic nerves lie at about the same level as the roof of the ethmoid sinuses.[7] It is not possible to irradiate the ethmoid and sphenoid sinuses without irradiating the optic nerves.

Lymphatics. Because of the sparsity of capillary lymphatics in the nasal cavity and paranasal sinus region, lymph node metastases are unusual. Elective irradiation of regional lymphatics is generally advised only in very advanced or recurrent, poorly differentiated tumors or those that extend into an area rich in capillary lymphatics (e.g., nasopharynx).

Paranasal sinuses. The anterior ethmoid air cells extend to within 1.0 cm of the anterior skin surface in the medial canthal region; coverage of tumor in this region can best be accomplished by delivering most of the dose from an anterior portal, so that at least one eyeball can be spared the effect of high-dose irradiation.

The floor of the maxillary sinus lies inferior to the floor of the nasal cavity, especially in edentulous patients. The inferior border of the anterior portal usually extends to the lip commissure to ensure adequate coverage.

Obstruction of normal drainage channels is a natural consequence of cancer in the upper air passages. In the era of polytomography, opacified sinuses were often assumed to be involved unless surgically proven to be free of tumor. CT does not completely solve the problem of determining whether a sinus is cloudy because of tumor or obstructed ostia, although it often produces valuable clues; MRI seems more promising in this respect (Fig. 1). If the question cannot be answered radiographically, surgical exploration may be indicated if the results will dictate a major change in the treatment volume (e.g., frontal sinus clouding, which would result in a large volume of brain irradiation, or extensive disease in the maxillary sinus, which could result in irradiation of the eye).

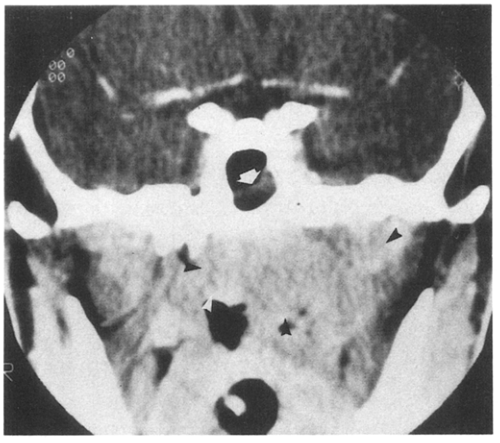
Perineural extension. Perineural tumor extension toward the central nervous system most commonly occurs in adenoid cystic carcinoma, but may occur with other histologies, particularly those recurrent after surgery. Radiographic evidence may be lacking. One commonly observed spread pattern includes extension through the cribriform plate into the anterior cranial fossa via the olfactory nerves. Another is extension into the middle cranial fossa or cavernous sinus via the infraorbital nerve or nerves that run through the superior orbital fissure. Subtle findings may be overlooked unless specifically sought. The pterygomaxillary fossa-infraorbital fissure should be carefully scrutinized with thin (3 mm) CT sections, preferably in both coronal and axial planes. The cribriform plate-olfactory groove region should always be studied coronally; MRI is probably a better choice than CT for detection of early invasion at this site. Generous coverage of the base of skull is mandatory when such extension is suspected.

Base of skull. A multiprojection radiographic evaluation is necessary to appreciate the 3-dimensional relationships of tumor to the base of the skull. Thin-section axial CT (1.5 mm to 4 mm, depending on the circumstances) adequately demonstrates tumor extensions in the anteroposterior dimension but is less able to visualize superoinferior spread. Direct coronal CT studies are usually done off-axis and with some discomfort to patients, especially elderly patients who cannot comfortably hyperextend the neck. Dental fillings also degrade the coronal CT image. Direct sagittal CT is impractical. Coronal or sagittal reformations are of poor resolution. In patients with suspected skull base erosion, there is a significant advantage for MRI at the cribriform plate, basisphenoid, and floor of the middle cranial fossa because of the ease of doing sagittal and coronal sections.[37] MRI has the added advantage of producing consistently high-quality images of the cavernous sinus in the coronal projection.

Radiation therapy technique

The irradiation technique emphasized an anterior portal with 1 or 2 posteriorly tilted wedged lateral portals (Fig. 2). The weights of the given doses (at Dmax) to the anterior and lateral field(s), respectively, were usually 2:1 or 3:1 in favor of the anterior field to avoid excessive irradiation to the contralateral eye.

Even when the lesion was thought to be rather localized, the initial treatment volume was generous; field reductions were often made at 4500–5000 cGy. For limited lesions of the nasal cavity, the initial treatment volume included the medial maxillary sinus, ethmoid sinus,



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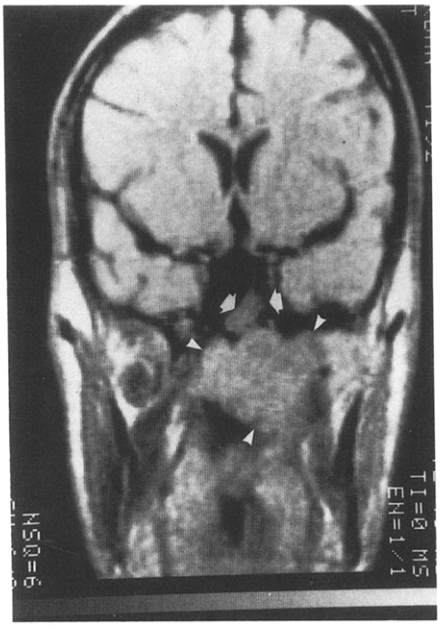
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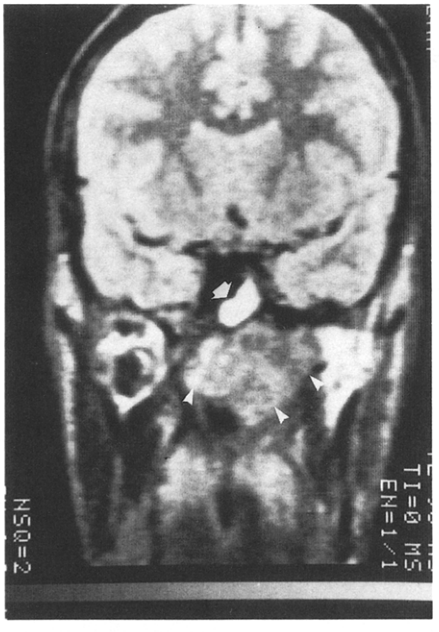
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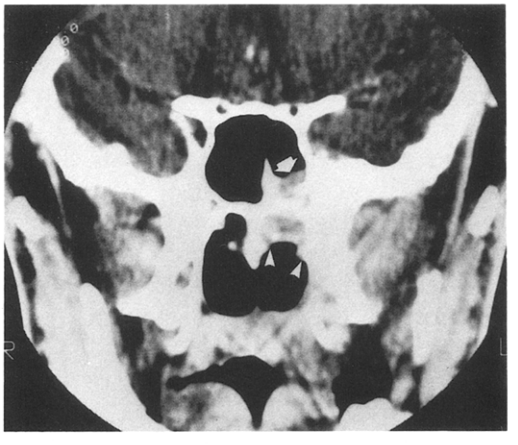

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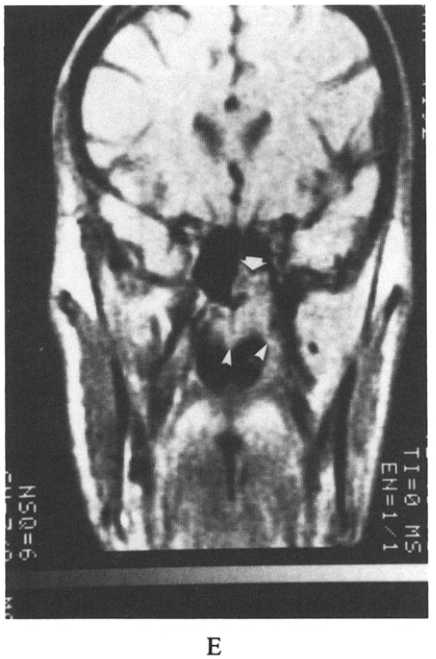
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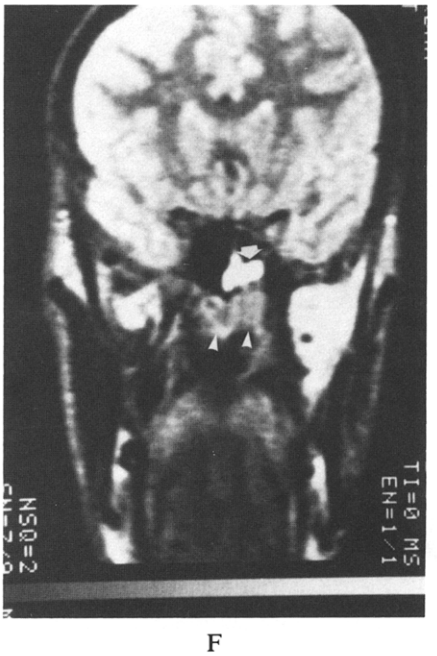
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medial orbit, nasopharynx, sphenoid sinus, and base of skull (Fig. 2A).

Ethmoid sinus and advanced nasal cavity tumors were similarly managed (Fig. 2B–D). A reduced anterior portal was often incorporated into the treatment plan to concentrate the dose to the major bulk of disease. If the ethmoid sinuses were extensively involved, a portion of the orbit (i.e., $\frac{1}{2}$ to $\frac{3}{4}$) was included in the initial treatment volume, even when there was no radiographic evidence of tumor extension into the orbit. In the pre-CT era, many patients with advanced lesions were treated without field reduction to the orbital margin because the precise limits of the tumor were often ill-defined. In more recent years, field reductions at the orbital margin have usually been made after 4000–4500 cGy tumor dose (180 cGy per fraction).

Forty-five patients were treated with external beam irradiation alone (24 continuous course, 21 split course).[24] Minimum tumor doses were most commonly 6000 cGy to 7000 cGy (median dose, 6600 cGy; mean dose, 6550 cGy), usually specified at the 90% of maximum isodose line. Treatment was usually (43 patients) administered once a day, 5 fractions per week, at 180–190 cGy per fraction; 2 patients received 7440 cGy and 7680 cGy, respectively, with 2 fractions per day.[26]

Three patients with nasal cavity lesions received a radium needle boost following 5000–6000 cGy external beam (2 patients) or a radium implant alone (1 patient). All external beam irradiation was by ^{60}Co or a 2 MV Van de Graaff generator.

RESULTS

Local control

Of 24 recurrences at the primary site, 10 occurred greater than 2 years after treatment. The distribution of primary site failures according to histologic type and time after treatment is shown in Figure 3.

Although adenoid cystic carcinomas were initially quite responsive, 5 of 6 patients with these tumors developed late primary recurrence at 40, 48, 60, 60, and 148 months. One patient, whose treatment consisted of 6500 cGy followed 2 months later by resection of a small area of residual disease, remains free of disease 15 years following treatment of a Stage I adenoid cystic carcinoma of the nasal cavity.

The local control results according to histology are shown in Figure 4. With the exception of adenoid cystic carcinoma (17% local control at 15 years), the ultimate local control rates for all histologies were in the range of 40% to 60%. The 10- and 15-year actuarial local control rates for the 42 patients with histologies other than adenoid cystic carcinoma were 52% and 42%, respectively.

The local control results for all histologies according to tumor stage are shown in Figure 5. There were no local failures in Stage I (7 patients). For Stage II and III disease, the local control rates at 10 years were 53% and 30%, respectively. There were no differences in local control between continuous-course and split-course irradiation.

Geographic tumor miss occurred in 5 patients. Two of the failures occurred in the brain in patients who had documented intracranial tumor extension prior to irradiation. Two patients with nasal cavity tumors developed recurrence outside of the high-dose field in the maxillary sinus. One patient with an adenoid cystic carcinoma of the sphenoid sinus presumably developed retrograde perineural extension to the hard palate 3.5 years after treatment.

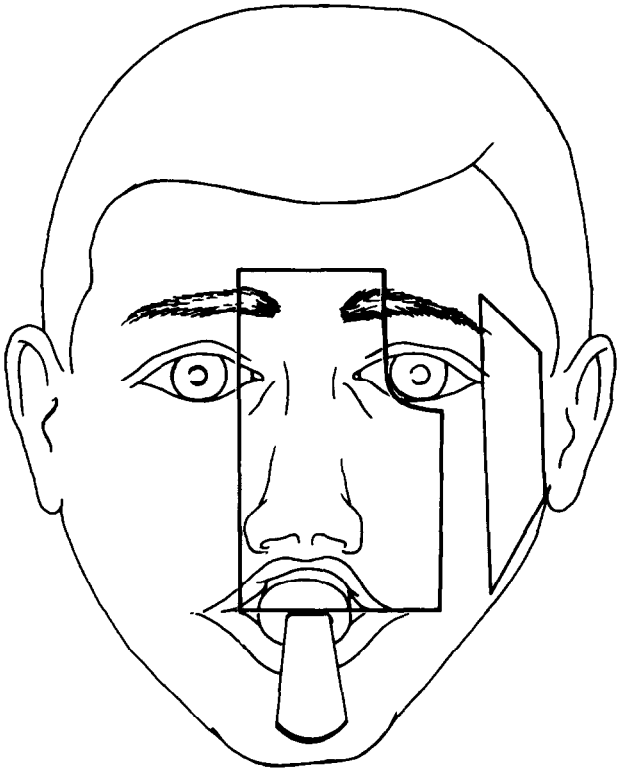
Surgical (7) or irradiation (1) salvage of primary failure was attempted in 8 patients and was successful in 2 patients (i.e., 8% of the 24 primary failures). Surgical salvage was not attempted in the remaining 16 patients because of unresectable primary or distant metastastic disease (14), patient refusal (1), or general debilitation (1).

Intracranial tumor extension was thought to be present at diagnosis in 8 patients, based on polytomography (8), angiogram (4), CT (2), biopsy proof (2), or brain scan or EEG (5). There were 4 esthesioneuroblastomas, 2 adenocarcinomas, 1 squamous cell carcinoma, and 1 adenoid cystic carcinoma. One patient who died of distant metastases at 12 months with local control was excluded from the control analysis. Disease in 3 (43%) of 7 patients remained locally controlled 3.5, 4, and 9 years, respectively, following treatment of adenocarcinoma (1) or esthesioneuroblastoma (2). Local failures occurred in 4 patients at 2, 3.5, 5, and 12.5 years, respectively.

Regional and distant metastases

Death due to neck failure alone was not observed. Forty-four patients presented with N0 neck disease. Elective neck irradiation was given to 22 patients who were

Fig. 1. Conventional polytomography is rather poor at distinguishing obstructive sinus disease from gross tumor involvement. CT and MRI are helpful. (A) Coronal CT with gross tumor mass at the base of skull (arrows). In the floor of the sphenoid sinus is a soft tissue density (arrowhead) that, because of lucent areas within it, was thought to represent fluid. (B) A T1-weighted coronal MRI at the same level is of no help in determining the nature of the sphenoid sinus disease, because the signal from the tumor mass is approximately the same as that from the density in the sinus. (C) However, on the T2-weighted image, the disease in the sphenoid sinus (arrowheads) is clearly distinguished from the tumor mass (arrows); such an appearance is most consistent with a fluid-filled sinus. (D) Coronal CT from an adjacent area of the same patient. The appearance of the tissues in the sphenoid sinus (arrowhead) does not have lucent areas within it, as in (A), so there is no clue as to whether the changes are those of tumor or obstruction. (E) The T1-weighted image is not helpful in distinguishing tumor from fluid and inflammatory debris. (F) The T2-weighted image is highly suggestive of fluid rather than gross disease in the sphenoid sinus.



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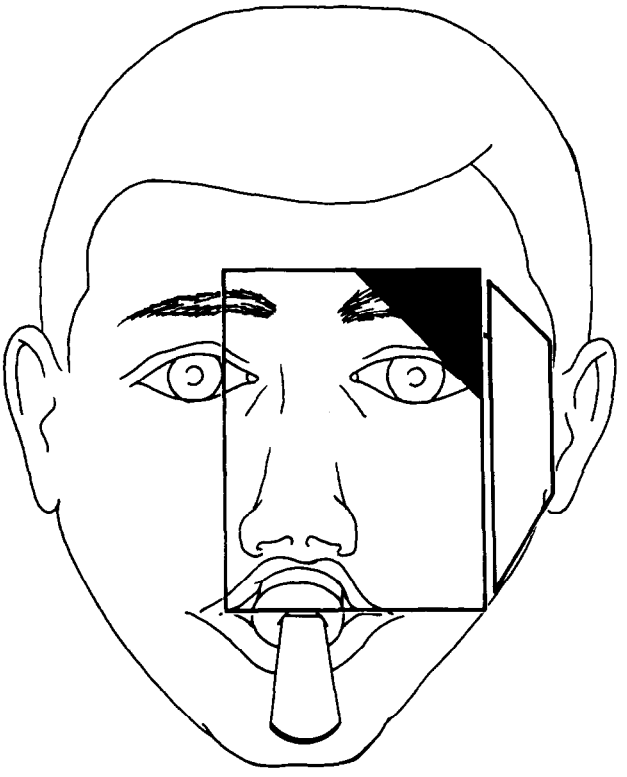

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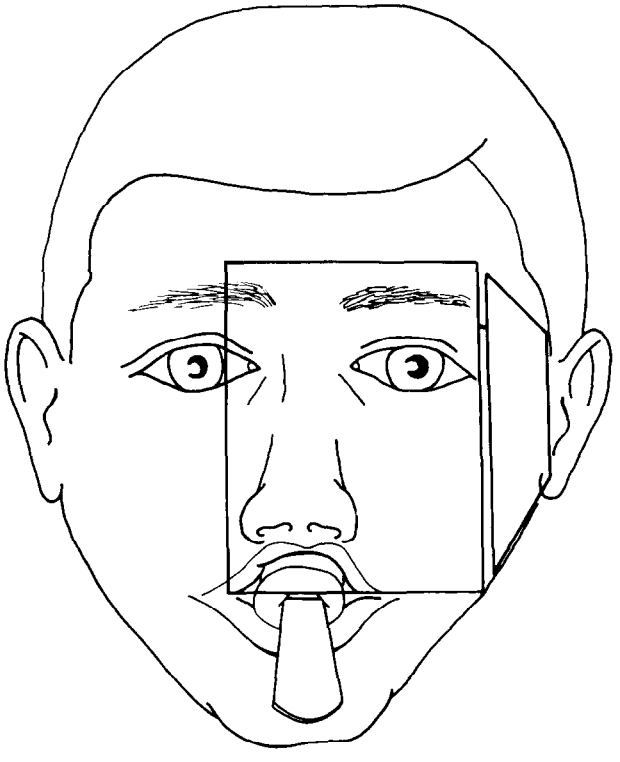

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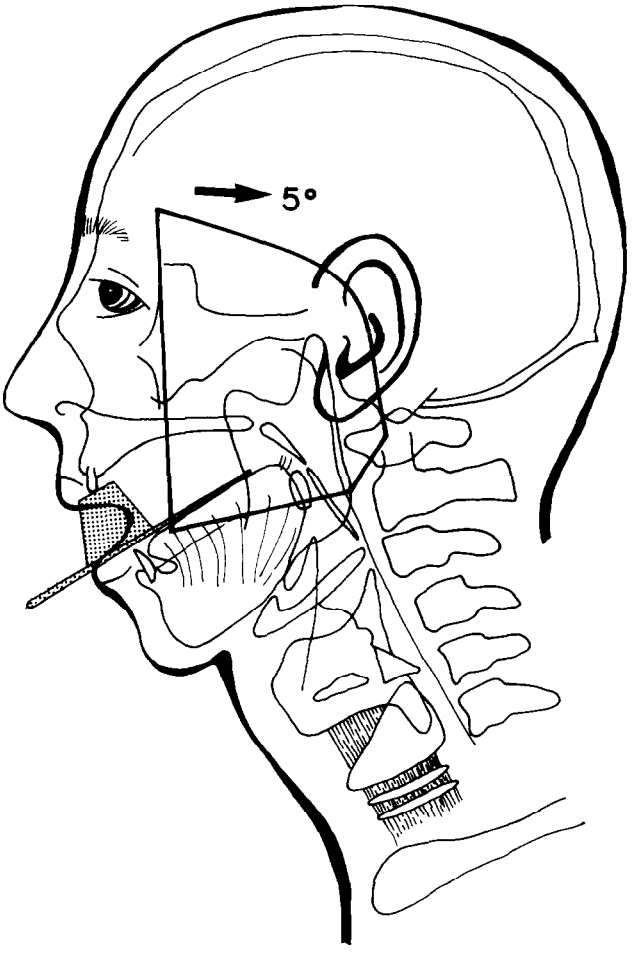

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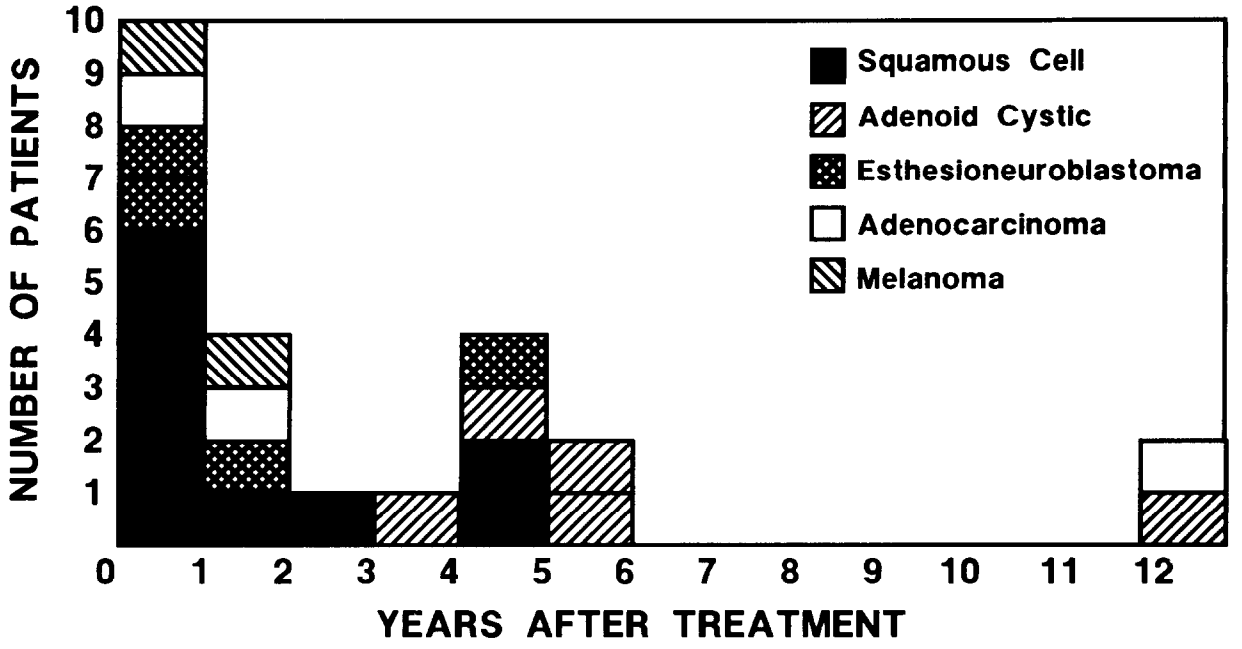

Fig. 3. Time to detection of recurrence at the primary site in 24 patients who developed locally recurrent cancer, according to histology.

thought to have a greater than 20% risk of having occult disease in neck nodes; none developed recurrence in the neck. Of 22 patients who did not receive elective neck irradiation, 2 developed lymph node metastases in the absence of primary failure; both were successfully salvaged by radical neck dissection. Of 4 patients who presented with clinically positive lymph nodes, no neck failures occurred following high-dose radiation therapy alone.

Four patients (2 adenocarcinoma, 1 melanoma, and 1 esthesioneuroblastoma) died of distant metastasis alone with apparent disease control above the clavicles.

Survival

Actuarial survival[11] for the entire patient group is shown in Figure 6. The 5-, 10-, 15-, and 20-year survival rates were 52%, 30%, 22%, and 22%.

The 5-, 10-, and 15-year continuously disease-free survival rates for the entire patient group were 45%, 36%, and 27%, respectively. Continuously disease-free survival rates according to tumor stage are shown in Figure 7. The 10-year continuously disease-free survival rate for Stage I was 86%; the single failure was a submandibular lymph node metastasis at 10 months that was successfully salvaged by radical neck dissection. The 10-year

Fig. 2. Initial external beam treatment volumes for tumors of the nasal cavity and ethmoid sinuses. The diagrams are schematic; the actual fields used are shaped with Lipowitz's metal to conform to patient and tumor anatomy. (A) For limited lesions of the nasal cavity, the initial anterior treatment portal includes the entire ipsilateral nasal cavity, the medial maxillary sinus, and the ethmoid sinus. The field edge usually transects the eye at the medial limbus and encompasses the base of skull by approximately 1.0 cm. (B) For tumors of the ethmoid sinuses and advanced tumors of the nasal cavity with minimal orbital involvement, the major lacrimal gland and lateral upper eyelid are shielded on the anterior portal. The portal usually extends 2.0 cm above the base of skull. The field edge extends 1.5 to 2.0 cm across the midline to encompass the entire nasal cavity and ethmoid/sphenoid complex and the medial aspect of the contralateral orbit (usually to the contralateral medial soft tissue canthus). The right inferior border generally extends to or near to the lip commissure. During treatment, the patient is instructed to gaze straight ahead. The tongue is displaced out of the treatment field by a tongue blade and cork. (C) When there is advanced orbital invasion, all of the orbital contents are irradiated. (D) The superior border of the lateral fields is at least 1.0 cm above the base of the skull. If intracranial extension is demonstrated or suspected, the superior border is raised 2 to 3 cm. The anterior edge of the lateral field is at the lateral bony canthus, and the portal is angled 5° posteriorly so as to avoid exit irradiation of the contralateral eye. The portal encompasses the posterior ethmoid air cells, posterior maxillary sinus, posterior nasal cavity, the sphenoid sinus, nasopharynx, posterior half of both orbits, the pterygoid plates, infratemporal fossa, and parapharyngeal lymph nodes. The posterior border is just anterior to the external auditory canal and is shaped so as to exclude the brain stem and spinal cord. (A, B, C reprinted with permission from *Int. J. Radiat. Oncol. Biol. Phys.*, Vol. 9, J.T. Parsons *et al.*, "The Effects of Irradiation on the Eye and Optic Nerve," Copyright 1983, Pergamon Press, Ltd. (Figs. 1A, 1C, 1D, p. 610). D reprinted with permission from *Principles and Practice of Radiation Oncology*, C.A. Perez and L.W. Brady (editors), Chapter 25, "Cancer of the Nasal Cavity and Paranasal Sinuses," by J.T. Parsons and R.R. Million. Philadelphia, J.B. Lippincott, 1987 (Fig. 25-9E, p. 509).)

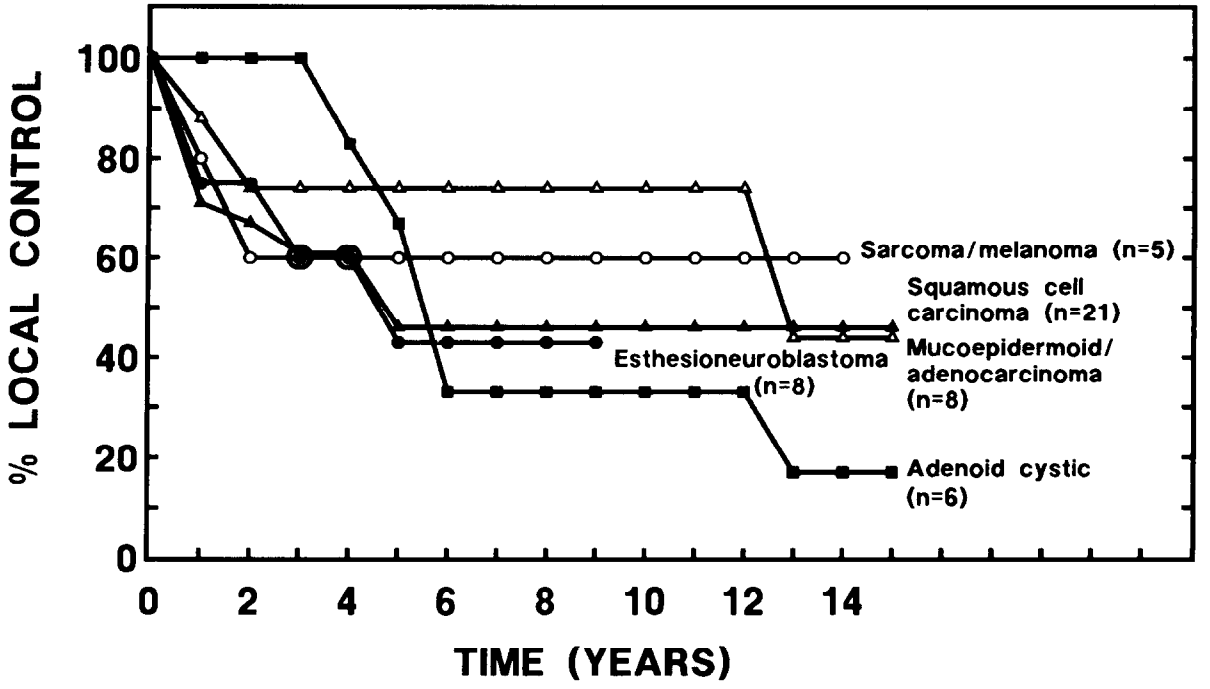

Fig. 4. Actuarial local control according to histologic type (for all stages combined).

continuously disease-free survival rate for each succeeding stage was approximately half that of the preceding stage (42% for Stage II, 22% for Stage III).

The 10-year continuously disease-free survival rate for 8 patients with mucoepidermoid carcinoma or adenocarcinoma was 47%; for 21 patients with squamous cell carcinoma, 42%; for 6 patients with adenoid cystic carcinoma, 33%; and for 5 patients with sarcomas or malignant melanoma, 30%. The 9-year rate for 8 patients with esthesioneuroblastoma was 25%.

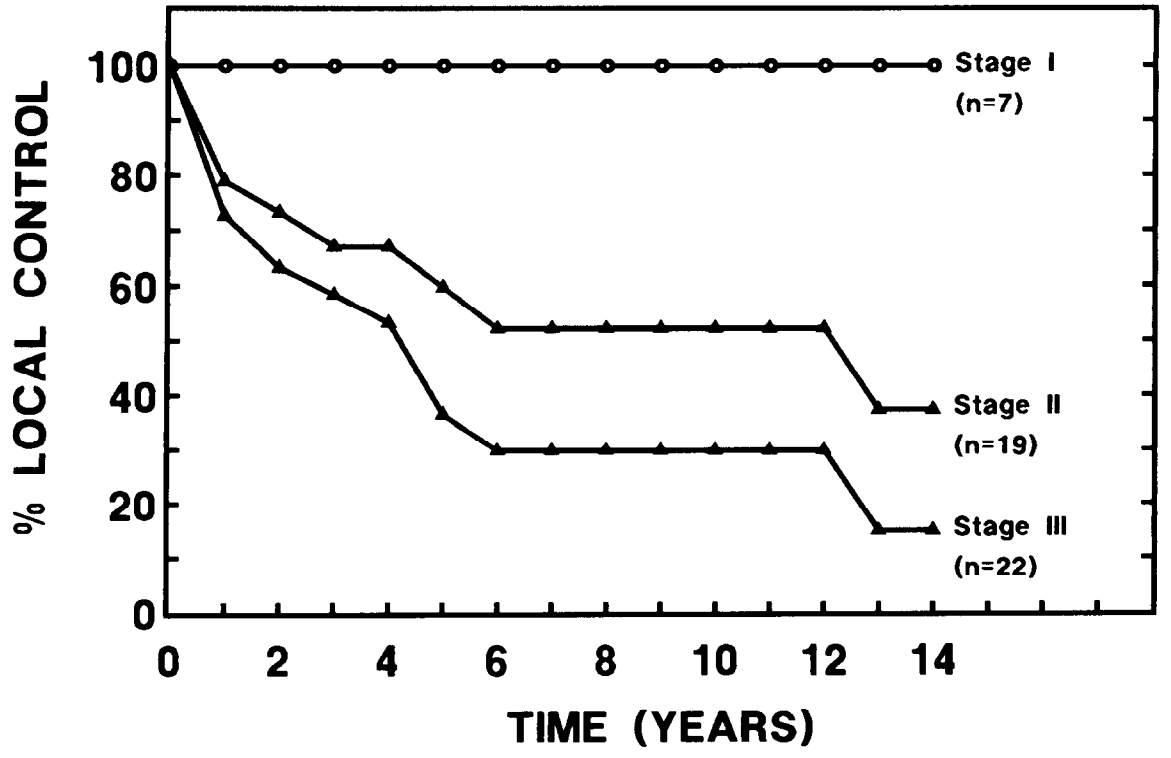

Fig. 5. Actuarial local control according to tumor stage (for all histologies combined).

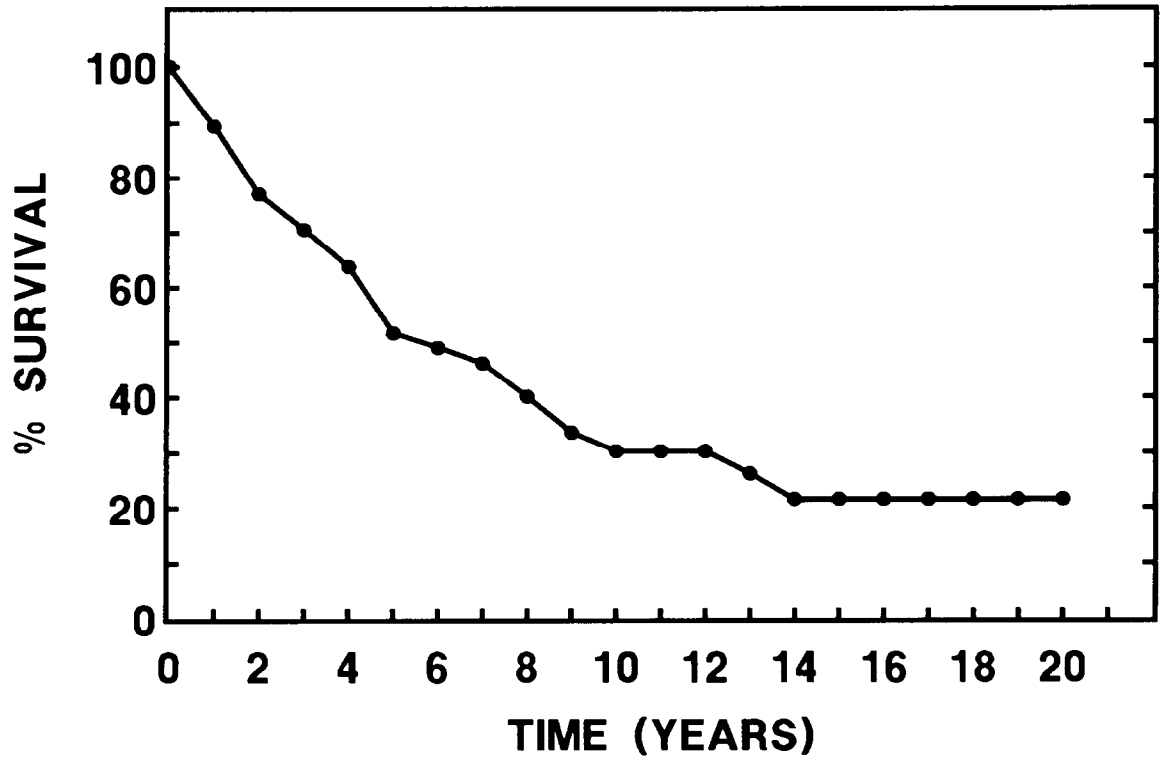

Fig. 6. Actuarial survival for all 48 patients.

Complications

Central nervous system. Transient central nervous system syndrome[33] was noted in 5 patients (10%). There was no documented brain necrosis or radiation myelitis. One patient developed a cerebrospinal fluid leak, ataxia, and disorientation during a course of irradiation after 5500 cGy had been administered. Symptoms abated after a 1-week rest interval.

Soft tissue/bone. No soft tissue necroses occurred. Three patients developed bone exposures of the maxilla; two were precipitated by dental extractions. Complications were minimally symptomatic and resolved sponta-

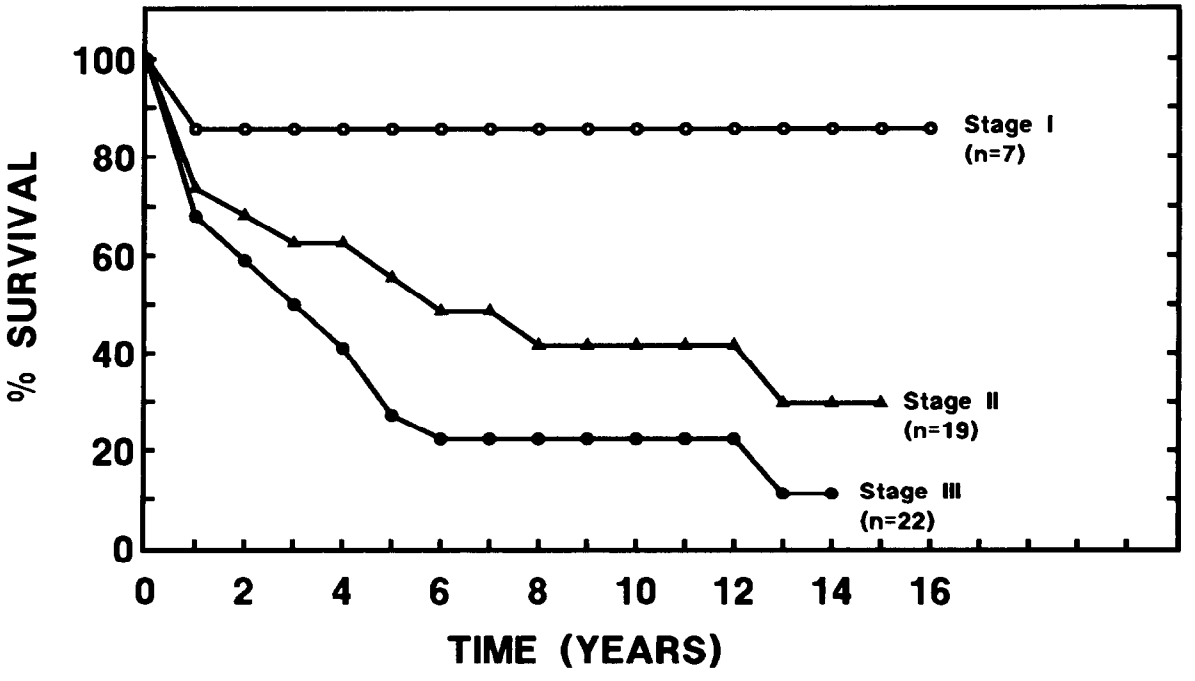

Fig. 7. Continuously disease-free survival according to tumor stage.

neously in 2 of the 3 patients. In the third, extensive surgical debridement was required, which resulted in a permanent oral-antral fistula.

Small (<1 cm) asymptomatic nasal septal perforations were incidentally noted in 2 patients at 5 and 7 months. One patient developed nasal synechiae leading to unilateral occlusion and 2 others developed approximately 50% stenosis. This problem can usually be avoided by using petrolatum swabs and nasal douches with a dilute saline solution until mucosal healing is complete.

Eye/optic nerve. Unilateral blindness secondary to radiation retinopathy or optic nerve injury occurred in 16 (33%) of 48 patients between 6 and 60 months following treatment (mean 25 months, median 26 months). Four patients (8%) (2 with Stage II malignant melanoma of the nasal cavity, 1 with Stage II squamous cell carcinoma of the nasal cavity, and 1 with Stage III, recurrent esthesioneuroblastoma) developed bilateral blindness due to bilateral optic neuropathy (2 patients) or a combination of ipsilateral radiation retinopathy and contralateral optic neuropathy (2 patients). In none of the 4 patients who developed bilateral blindness was either orbit definitely involved by tumor. Onset of blindness in the second eye occurred at 17, 35, 46, and 90 months, respectively. Since not all patients survived long enough to be at risk for development of blindness secondary to treatment, an actuarial cumulative probability of developing unilateral or bilateral blindness was calculated, scoring death without visual loss as a censoring event (Fig. 8). Sixty-three percent of patients who survived for 8–15 years after irradiation developed unilateral blindness and 15% were bilaterally blind.

Miscellaneous. Four patients (8%) developed serous otitis media requiring pneumatic equalization tubes. Acute or chronic sinusitis occurred in 5 patients and required Caldwell-Luc or nasal antrostomy for diagnosis and drainage in three. Another patient developed a single episode of erysipelas 4 months after treatment, and 1 patient was treated for meningitis 4.5 years after treatment.

DISCUSSION

Because of the low risk of regional and distant metastases from malignant tumors of the nasal cavity and ethmoid/sphenoid sinuses, local control is almost tantamount to cure. With the exception of adenoid cystic carcinoma, irradiation was able to provide long-term local control in approximately half of all patients with a variety of histologies and disease stages. Long-term follow-up is mandatory. At the time of our last analysis (1981) of this patient group,[21,27] there were no local failures later than 2 years after treatment in histologies other than adenoid cystic carcinoma; since that time, late failures have been observed in most of the other histologies. Because of the lack of an accepted staging system, one cannot readily compare these results with those of other radiation or surgical series.

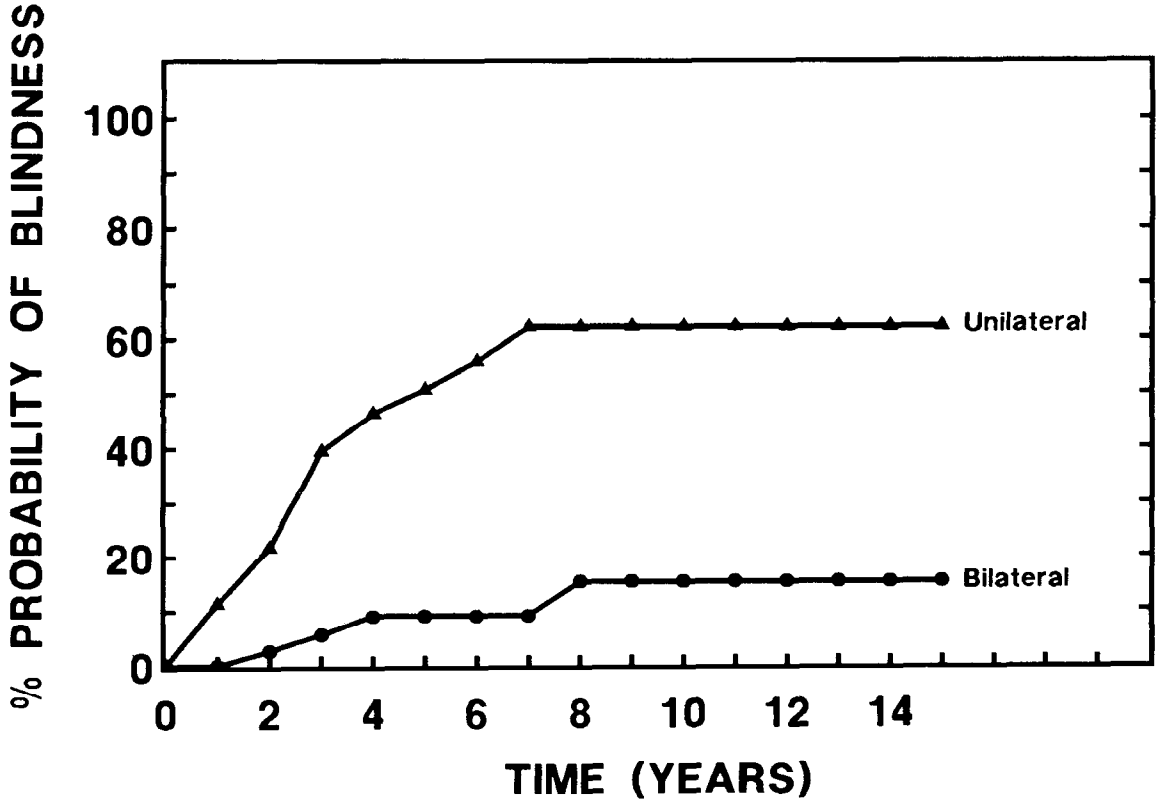

Fig. 8. Actuarial probability of developing unilateral or bilateral blindness following irradiation.

The advantages of using radiation therapy alone for these tumors are that a major operation is avoided; there is no risk of immediate operative death; and it is applicable to many patients who have surgically unresectable disease. The chief disadvantage is the risk of bilateral blindness. The advantages of using an operation for these lesions are that the risk of bilateral blindness is low; an accurate assessment of disease extent is possible; the bulk of tumor can often be removed; and once the patient has recovered from the operation, additional delayed complications are rare. The disadvantages are the risk of life-endangering surgical complications and when craniofacial resection is utilized, an operative mortality rate that approaches the risk of bilateral blindness in the present series. Although it may be argued that by using operation, the need for irradiation may be eliminated altogether, most authors still recommend either preoperative or postoperative irradiation when surgical treatment is undertaken.[9,30]

The overall incidence of unilateral blindness in this series was 16/48 (33%), a figure that is lower than the incidence of gross orbital extension (46%) at presentation. At the Princess Margaret Hospital, where lower total doses of irradiation were administered, Beale and Garrett reported 5-year survival results for nasal cavity and ethmoid sinus tumors that were similar to those reported in the present series but with a lower rate of radiation-induced eye injury than we report here.[3] In the Beale and Garrett series, 32 (35%) of 91 patients with nasal cavity, ethmoid sinus, and sphenoid sinus tumors underwent surgical resection, which presumably included orbital exenteration in a number of patients. In the present series, only 12% of patients underwent planned resection. In the literature, immediate visual loss secondary to orbital exenteration is generally not regarded as a treatment complication, whereas visual loss that results from irradiation (which is often delayed for 1.5–2 years) is regarded as a severe complication.[6] The disadvantage of irradiation is that there is also a risk of bilateral blindness secondary to optic neuropathy. Four patients in the present series developed bilateral blindness. In two, unilateral visual loss had been expected at the outset because the ipsilateral orbit was irradiated to a high dose owing to extensive disease in the adjacent maxillary or ethmoid sinuses; unexpected optic neuropathy involving the contralateral eye led to total visual loss. Two other patients in whom no orbital extension was apparent before irradiation developed total visual loss secondary to bilateral optic neuropathy. From previous analyses, it is apparent that fraction size as well as total dose is critical.[25] In the past, computer isodose distributions were usually generated only at the central axis. In more recent years, off-axis treatment plans at the level of the eyes and optic nerves have become routine and demonstrate that, with the technique used at the University of Florida, the dose to the optic nerve is frequently about 10% higher than the minimum tumor dose prescribed on the central axis treatment plan. A daily dose of 180 cGy at the 90% of maximum isodose distribution at the central axis often results in a daily dose of 200 cGy to one or both optic nerves.

Efforts to alleviate the problem of bilateral blindness should focus on reducing the dose to the optic nerves and improving the homogeneity of dose within the treatment volume. While CT and MRI offer considerable help in planning tighter treatment volumes around the eye, they are not of much help with regard to the optic nerves, which are situated so that portions of both must usually remain in the treatment volume for the entire treatment. One means of reducing the dose would be to operate on those lesions that are resectable, and use postoperative irradiation to approximately 6000 cGy at approximately 180 cGy per fraction, which should produce a very low risk of optic nerve injury. Unfortunately, many of these tumors are far advanced and unresectable or the patients are medically inoperable or refuse to accept an operation of such magnitude. Close attention should be paid to off-axis dosimetry at the level of the optic nerves and to known time-dose relationships.[23] A customized tissue compensator for the anterior portal may improve the homogeneity of the dose. Possibly hyperfractionation may result in a differential sparing of the optic nerve relative to acute effects tissues and tumor; this approach has only been tried in a few patients with sinus tumors at the University of Florida.

All patients in the present series were treated with ^{60}Co or 2 MV X rays; in the last few years, higher energy (e.g. 8 MV) X rays have often been used to achieve more homogeneous dose distributions.

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