

INTENSITY-MODULATED RADIATION THERAPY FOR MALIGNANCIES OF THE NASAL CAVITY AND PARANASAL SINUSES

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Purpose: To report the clinical outcome of patients treated with intensity-modulated radiation therapy (IMRT) for malignancies of the nasal cavity and paranasal sinuses.

Methods and Materials: Between 1998 and 2004, 36 patients with malignancies of the sinonasal region were treated with IMRT. Thirty-two patients (89%) were treated in the postoperative setting after gross total resection. Treatment plans were designed to provide a dose of 70 Gy to 95% or more of the gross tumor volume (GTV) and 60 Gy to 95% or more of the clinical tumor volume (CTV) while sparing neighboring critical structures including the optic chiasm, optic nerves, eyes, and brainstem. The primary sites were: 13 ethmoid sinus, 10 maxillary sinus, 7 nasal cavity, and 6 other. Histology was: 12 squamous cell, 7 esthesioneuroblastoma, 5 adenoid cystic, 5 undifferentiated, 5 adenocarcinoma, and 2 other. Median follow-up was 51 months among surviving patients (range, 9–82 months).

Results: The 2-year and 5-year estimates of local control were 62% and 58%, respectively. One patient developed isolated distant metastasis, and none developed isolated regional failure. The 5-year rates of disease-free and overall survival were 55% and 45%, respectively. The incidence of ocular toxicity was minimal with no patients reporting decreased vision. Late complications included xerophthalmia (1 patient), lacrimal stenosis (1 patient), and cataract (1 patient).

Conclusion: Although IMRT for malignancies of the sinonasal region does not appear to lead to significant improvements in disease control, the low incidence of complications is encouraging. © 2007 Elsevier Inc.

Intensity-modulated radiation therapy, Paranasal sinus, Nasal cavity, Cancer.

INTRODUCTION

Tumors of the paranasal sinuses and nasal cavity are rare, representing 3–5% of all head-and-neck cancers and less than 1% of all malignancies (1–3). Given their proximity to critical normal tissue structures such as the skull base, central nervous system, orbits, and optic pathways, these cancers have historically posed a therapeutic challenge, particularly because they are often diagnosed at advanced stages because of their inconspicuous locations. Treatment modalities have traditionally been multidisciplinary, consisting of surgical resection when feasible or external beam radiation therapy. However, radiation therapy using conventional or conformal techniques has been associated with a number of potentially severe complications, leading to radiation-induced injuries to the visual pathways, central nervous system, and adjacent bony structures (4). Indeed, ocular toxicity after treatment is a significant complication among patients treated for tumors of the sinonasal region, and the incidence of unilateral and bilateral blindness from

radiation-induced retinopathy and optic neuropathy has been reported to be as high as 30% and 10%, respectively (5–9).

Intensity-modulated radiation therapy (IMRT) offers the potential to reduce dose to critical structures while maintaining desired doses to the gross tumor volume via optimized nonuniform beam intensities. Studies reporting clinical outcomes at other regions of the head and neck have demonstrated that the use of IMRT can lead to excellent local control and survival rates with minimal complications (10). Tumors of the skull base, including those involving the sinonasal region, appear to be especially well-suited to the use of IMRT, given the irregular contours of tumors and vital structures in this region and the lack of organ motion, allowing for accurate reproduction of field setup. Although preliminary analyses of treatment plans for the paranasal sinuses and nasal cavity suggest that significant normal tissue sparing can be achieved while maintaining desired dosages to the tumor, there are few data reporting on clinical

outcome for patients undergoing treatment with IMRT. We report here a series of 36 patients treated at the University of California, San Francisco (UCSF) with IMRT for tumors of the paranasal sinus and nasal cavity.

METHODS AND MATERIALS

Patient identification and characteristics

Between April 1998 and December 2004, 45 consecutive patients were treated with IMRT in the Department of Radiation Oncology at UCSF for malignancies of the nasal cavity and paranasal sinuses. The following patients were excluded from this analysis: 3 patients treated with boost IMRT after conventional radiation therapy; 3 patients treated for recurrent disease; and 3 patients with inadequate follow-up. Table 1 outlines the clinical and disease characteristics of the 36 remaining patients with histologically proven malignancies of the sinonasal region comprising the primary population of this analysis. The median age of the patients identified was 57 years (range, 27–84 years). Seventeen men and 19 women were included. Racial distribution was as follows: 25 Caucasian (69%), 5 Asian (14%), 3 Hispanic (8%), and 3 African American (8%).

The primary involved sites were: 13 ethmoid sinus, 10 maxillary sinus, 7 nasal cavity/septum, 2 accessory sinus, 2 sphenoid sinus, 1 orbital sinus, and 1 frontal sinus. Histology was: squamous cell

carcinoma (12 patients), esthesioneuroblastoma (7 patients), adenoid cystic carcinoma (5 patients), undifferentiated carcinoma (5 patients), adenocarcinoma (5 patients), mucoepidermoid carcinoma (1 patient), and neuroendocrine cancer (1 patient). All patients were retrospectively staged in accordance with 2003 American Joint Committee on Cancer staging classification. Distribution of T stage was: 3% Tis, 3% T1, 3% T2, 22% T3, and 69% T4. No patient had clinical or pathologic evidence of neck disease at the time of radiation treatment.

Pretreatment evaluation consisted of complete history and physical examination, complete blood counts, liver function tests, chest X-ray, and dental evaluation. All patients were imaged with computed tomography (CT) and MRI of the head and neck. Bone scans and CT scans of the abdomen or chest were obtained when clinically indicated. No definite policy existed regarding postoperative radiation therapy, but, in general, patients were referred for radiation therapy at the discretion of the treating surgeon when there was uncertainty about the completeness or adequacy of the excision based on intraoperative and pathologic findings. Thirty-two of 36 patients (89%) were treated with IMRT postoperatively after gross surgical resection. The type of surgery was dependent on the primary site, extent of disease, cosmetic considerations, and the discretion of the surgeon. In general, an attempt was made to maximize local control with preservation of cosmetic and functional outcome. The remaining 4 patients were treated with IMRT alone with definitive intent. Surgical approaches in postoperatively treated patients included transfacial resection (9 patients), transcranial resection (7 patients), combined transfacial and transcranial resection (10 patients), and unknown (6 patients). Surgical margins were microscopically positive in 19 cases, negative in 10, and unknown in 3. None of the patients underwent surgical neck dissection. The interval between surgery and the start of radiation therapy ranged from 6 to 68 days (median, 31 days). Eight patients (22%) received adjuvant chemotherapy, 6 concurrently with radiation therapy, and 2 before radiation therapy.

Patient immobilization and simulation

The head, neck, and, in some cases, the shoulders were immobilized in a hyperextended position using a perforated, thermoplastic head mask with the neck supported on a Timo cushion (S-type, Med-Tec, Orange City, IA) mounted on carbon fiber board (S-type, Med-Tec, Orange City, IA) that allowed patient positioning to be indexed. In some patients, hyperextension of the neck was not possible because of discomfort, and a neutral position was selected at the discretion of the physician. At the time of simulation, the isocenter on the initial simulation film was placed at the anticipated treatment isocenter and paired orthogonal X-rays were obtained to verify localization. Treatment planning CT scans and volumetric data were then obtained with the patient immobilized in the treatment simulation position. Serial CT scan slices, 3-mm thick, from the head down through the clavicles were obtained.

Target volume delineation

The gross tumor volume (GTV) was specified as the gross extent of tumor as demonstrated by preoperative CT imaging studies and physical examination. The clinical target volume (CTV) was defined as the GTV plus a margin of 1–2 cm to account for routes of microscopic disease spread. The planning target volume (PTV) contained an automated 0.3–0.5 cm expansion of the CTV surfaces to account for patient setup error. The GTV, CTV, and sensitive normal structures were delineated on serial

Table 1. Patient characteristics

Characteristic	No. of patients	%
Age		
≤60 years	19	53
>60 years	17	47
Gender		
Male	17	47
Female	19	53
Site		
Ethmoid	13	36
Maxillary	9	25
Nasal cavity	7	19
Accessory	2	6
Sphenoid	2	6
Frontal	1	3
Orbital	1	3
Histology		
SCC	12	33
Esthesio	7	19
Adeno	5	14
ACC	5	14
SNUC	5	14
Mucoepi	1	3
Neuroendo	1	3
T-stage		
Tis	1	3
T1	1	3
T2	1	3
T3	8	22
T4	25	69

Abbreviations: SCC = squamous cell carcinoma; Esthesio = esthesioneuroblastoma; Adeno = adenocarcinoma; ACC = adenoid cystic carcinoma; SNUC = sinonasal undifferentiated carcinoma; Mucoepi = mucoepidermoid; Neuroendo = neuroendocrine carcinoma.

treatment planning CT images. Structures considered to be critically at risk included the optic nerves, optic chiasm, orbits, lens, brainstem, and parotid glands. No overlap between the target volumes and uninvolved critical adjacent tissues was permitted.

Treatment of the neck was dependent on multiple factors. Two patients with palpable neck disease (upper jugular) before surgery underwent ipsilateral modified radical neck dissections followed by postoperative radiation. Elective neck dissection was not performed for the clinically negative neck on any patient. At the time of radiation therapy, no patient had evidence of gross nodal disease, defined as focal nodal necrosis or heterogeneity, or as short axial diameter exceeding 1 cm. Elective neck radiation was administered at the discretion of the treating radiation oncologist with consideration given to the extensiveness and lymphatic drainage of the primary tumor. Overall, 10 of 36 patients (27%) were treated with elective neck irradiation.

Dose specification, treatment planning, and delivery

Treatment plans were designed to provide a dose of 70 Gy to 95% or more of the GTV and 60 Gy to 95% or more of the CTV while sparing neighboring critical structures. Dose–volume histograms of the GTV and CTV as well as critical normal structures were retrospectively retrieved from out planning CT scans and used to calculate the maximum, mean, and minimum doses to each volume. For GTV and CTV, we evaluated the volume receiving less than 95% of the prescribed dose as quantitative endpoints to reflect tumor target coverage. For critical normal structures, our dose constraints were designed to limit the maximum dose to 1% of the volume to 54 Gy for the brainstem and optic nerves, 45 Gy for the spinal cord and optic chiasm, 60 Gy for the temporal lobes, and 25 Gy to 50% of the contralateral parotid gland.

All treatment plans were generated using an inverse IMRT planning system developed by the NOMOS Corporation (North American Scientific, NOMOS division, Cranberry Township, PA) either the Peacock, Version 1, or Corvus, Version 3.0, and Version 4.0 planning systems. Treatment was delivered using a computer-controlled auto-sequence multileaf collimator system (Siemens Medical Systems, Concord, CA), or the MIMiC (North American Scientific, NOMOS division, Cranberry Township, PA). Treatment was by continuous-course radiation with once-per-day treatment. Because our goal was to prescribe 1.8 Gy per fraction to the CTV daily, the GTV received a higher dose per fraction, typically 2.12 Gy per fraction. The treatment planning and delivery details employed at UCSF have previously been described (11).

Treatment of the neck used two methods. The first treated the primary tumor and the upper neck above the vocal cords with IMRT and the lower neck and the supraclavicular fossae with an anterior field. These two fields were matched with a split-beam technique. The second involved the use of an extended field IMRT technique that treated the primary tumor along with all regional lymph nodes including the supraclavicular nodes. For patients who received radiation to the regional lymph nodes, the upper neck or the high-risk subclinical region typically received 60 Gy, whereas the low neck and the supraclavicular region received 50–54 Gy. A detailed description of these techniques is presented elsewhere (12).

Follow-up

After completion of IMRT, patients were evaluated every 1–2 months for the first 6 months, then every 3 months for the next 6–12 months, every 4–6 months from 18 months through 3 years, and annually thereafter. Follow-up consisted of routine physical

examination, blood work, and review of systems. A baseline posttreatment MRI scan of the head and neck was obtained within 2–6 months after completion of IMRT and then yearly or when clinically indicated. Local control was judged to have been attained if there was no evidence of tumor growth at the primary site based on clinical and radiographic findings at follow-up. Regional failure was recorded separately if there was evidence of an enlarging cervical or supraclavicular mass distinct from the primary site. Patient follow-up was reported to the date last seen in clinic or to the date of expiration. Acute and late normal tissue effects were graded according to the Radiation Therapy Oncology Group/European Organization for the Treatment of Cancer radiation toxicity criteria (13).

Statistical analysis

The endpoints analyzed were overall survival, local control, and disease-free survival. All events were measured from the date of histologic diagnosis of the initial biopsy specimen. Median follow-up was 39 months (range, 6–82 months) for the entire patient population and 51 months among surviving patients (range, 9–82 months). Actuarial estimates of local control, disease-free survival, and overall survival were calculated using the Kaplan-Meier method, with comparisons among groups performed with two-sided log-rank tests (14). All statistical analysis was performed using SPSS (SPSS Inc, Chicago IL).

RESULTS

Dose–volume analysis

The median prescribed dose to the GTV was 70 Gy (range, 63–72 Gy), and median prescribed dose to the CTV was 58 Gy (range, 51–60 Gy). The average maximum, mean, and minimum doses delivered were 80 Gy, 72 Gy, and 39 Gy, respectively, to the GTV, and 79 Gy, 65 Gy, and 25 Gy to the CTV. Gross tumor volume and CTV coverage were excellent; an average of 6.4% of the GTV and 6.0% of the CTV received less than the prescribed dose respectively. The average maximum doses to the optic chiasm, contralateral optic nerve, and ipsilateral optic nerve were 44 Gy, 45 Gy, and 50 Gy. Tables 2 and 3 summarize dose–volume statistics for critical structures among the primary patient population.

Survival and disease control

As illustrated in Fig. 1, the 2-year and 5-year estimates of overall survival for the entire patient population were 69%

Table 2. Maximum dose to critical structures

Structure	Max dose (Gy)
Optic chiasm	52.3 ± 5.1
Optic nerve (ipsilateral)	59.1 ± 7.7
Optic nerve (contralateral)	45.2 ± 6.1
Eye (ipsilateral)	54.4 ± 3.9
Eye (contralateral)	41.6 ± 4.0
Lens (ipsilateral)	19.9 ± 8.1
Lens (contralateral)	11.2 ± 6.3

Data presented are median of maximum doses of all patients.

Table 3. Mean dose to critical structures

Structure	Mean dose (Gy)
Optic chiasm	39.5 ± 4.2
Optic nerve (ipsilateral)	48.1 ± 3.7
Optic nerve (contralateral)	38.2 ± 5.5
Eye (ipsilateral)	29.5 ± 6.9
Eye (contralateral)	16.9 ± 5.2
Lens (ipsilateral)	14.0 ± 7.9
Lens (contralateral)	6.7 ± 5.4

Data presented are median of mean doses of all patients.

and 45%, respectively. Eighteen patients were alive at the time of this analysis. Among the 18 patients who died during the evaluation period, 9 died as a result of recurrent or persistent primary tumor, 3 from metastatic disease, and 2 of intercurrent disease. The cause of death was unknown in 4 patients.

After radiation treatment, 2 patients continued to have persistent disease, both of whom progressed locally with follow-up. An additional 12 patients experienced a local recurrence at a median of 13.4 months (range, 4–31 months) from the time of initial diagnosis. Thus a total of 14 patients experienced progression of local disease. For the entire patient population, the 2-year and 5-year estimates of local control were 62% and 58%, respectively. There was no difference in local control according to surgical margin status. Nine of 19 patients (47%) with positive microscopic margins developed a local recurrence compared with 4 of 10 patients with negative margins (40%). The 5-year rate of local control for patients with microscopically positive margins was 52% compared with 59% for patients with negative margins ($p = 0.55$). Figure 2 illustrates local control for the entire patient population.

The first site of disease failure was local in 13 patients and distant in 1 patient. There were no isolated regional

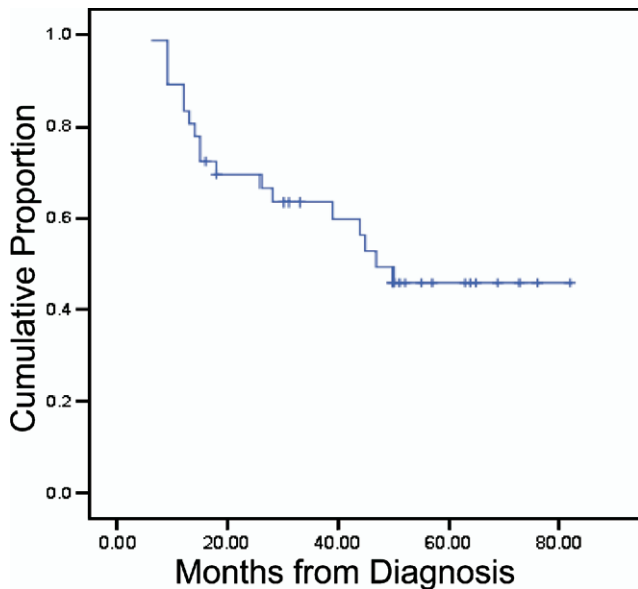


Fig. 1. Overall survival for the entire patient population.

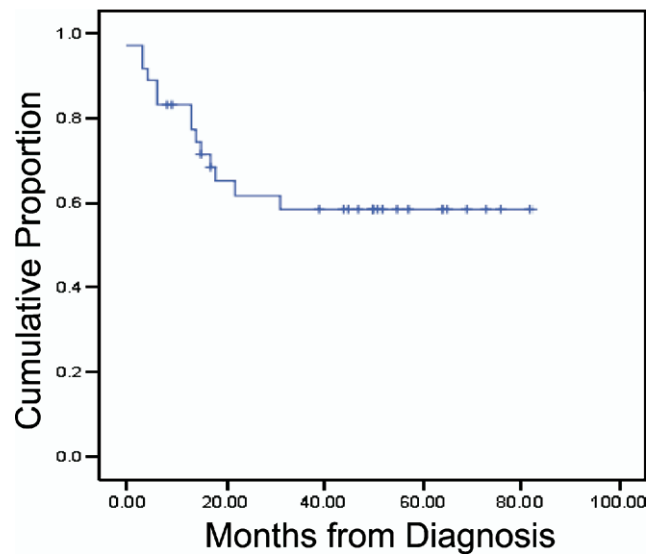


Fig. 2. Local control for the entire patient population.

failures in the neck. All local failures were considered to have been within the GTV. A total of 5 patients developed distant metastasis during the evaluation period, all in the lungs. The median time to the development of distant metastasis was 31 months (range, 9–50 months). One patient, with squamous cell carcinoma of the maxillary sinus, experienced a regional failure in the irradiated neck subsequent to the development of both local recurrence and distant metastasis. Among the 18 living patients, 14 were free of disease at the time of last follow-up visit. As depicted in Fig. 3, the 2-year and 5-year estimates of disease-free survival for the entire patient population were 62% and 55%, respectively.

Acute sequelae of treatment

Information related to acute toxicity was available for all 36 patients treated. The most frequent complication in the

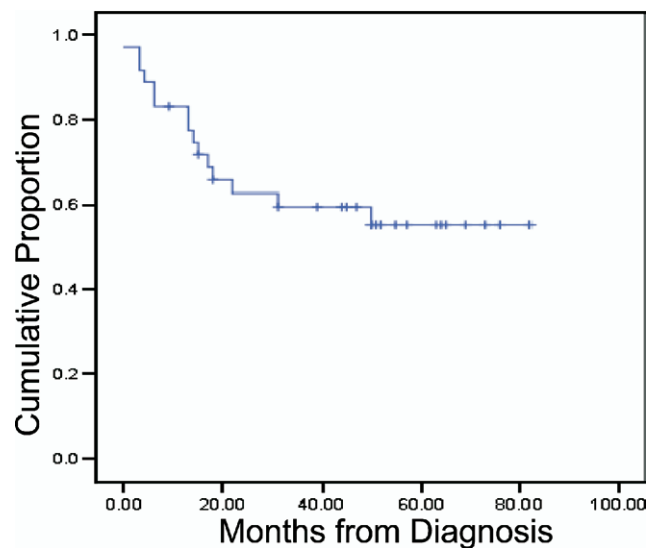


Fig. 3. Disease-free survival for the entire patient population.

acute setting was mucositis, which was scored as Grade 1 in 19 patients, Grade 2 in an additional 11 patients, and Grade 3 in 6 patients. The next most frequent side effect of radiation treatment was conjunctivitis, which was scored as Grade 1 in 18 patients, Grade 2 in 10 patients, and Grade 3 in 1 patient. Other reported complications in the acute setting included keratitis (1 patient), cellulitis (1 patient), dacryocystitis (1 patient), and parotiditis (1 patient). All of these reactions resolved with conservative medical management. The targeted dose delivery of IMRT did not adversely affect the pericranial flap or reconstruction site in any of the transcranial cases.

Chronic sequelae of treatment

Information related to chronic toxicity, including visual acuity, was available for 30 of the 36 patients treated. No patients experienced a complete loss of vision as a result of treatment. One patient treated for squamous cell carcinoma of the ethmoid sinus developed chronic xerophthalmia without visual compromise as a sequelae of treatment; 1 additional patient experienced chronic lacrimal stenosis after treatment for a squamous cell carcinoma of the lacrimal sac; and 1 patient developed an early cataract approximately 2 years after radiation treatment for an ethmoid sinus esthesioneuroblastoma.

A total of 9 patients experienced various forms of non-ocular late complications secondary to radiation. Three patients were found to have eustachian tube dysfunction after complaining of vestibular symptoms and after treatment for cancers of the maxillary sinus. Two other patients treated for tumors of the ethmoid sinus developed saddle nose deformities. An additional patient treated for an adenoid cystic carcinoma of the nasal cavity/ethmoid sinus developed a sinocutaneous fistula subsequently repaired surgically. One developed sudden-onset facial pain after treatment for adenoid cystic carcinoma involving the maxillary sinus. One patient treated for squamous cell carcinoma of the orbital sinuses developed chronic osteomyelitis. One patient treated for a squamous cell carcinoma of the maxillary sinus developed radiation necrosis of the gyrus rectus muscle resulting in gaze limitation.

DISCUSSION

Although numerous treatment planning studies have demonstrated through dosimetric comparisons that IMRT can potentially offer a superior dose distribution for the treatment of sinonasal tumors in comparison to three-dimensional conformal and conventional methods, there are few data reporting on actual outcome of patients treated in this manner (15–18). The results of the present study strongly suggest that the theoretical advantages instilled with IMRT at the time of treatment planning do indeed translate into tangible benefits for patients treated in the clinical setting with reasonably mature follow-up. The relatively low incidence of complications observed in the present study is particularly reassuring given that tumors originating from

the nasal cavity and paranasal sinuses have long posed a distinct treatment challenge to clinicians because of their advanced stage at presentation and their propensity to involve adjacent critical structures.

For patients treated with radiation therapy for malignancies of the sinonasal region, it has been established that although high doses are required to achieve local tumor control, the proximity of cancer to sensitive normal tissue often results in suboptimal outcomes both in terms of disease control and radiation-induced morbidity (19). Because IMRT allows for a substantially sharp dose fall-off gradient between the target and surrounding normal tissue, it has been proposed as a means of improving outcomes for this disease. Adams *et al.* (17) compared three-dimensional conformal and IMRT treatment plans for 6 patients already treated with conventional techniques for maxillary sinus tumors and concluded using dose–volume histogram analysis that IMRT improved PTV homogeneity and reduced doses to crucial structures such as the optic pathways, brainstem, and parotid glands. More recently, Tsien *et al.* (18) retrospectively replanned 13 patients previously treated with conventional techniques for sinonasal tumors with inverse planning IMRT. The authors then used a class solution cost function to evaluate theoretical clinical outcomes and showed that IMRT can potentially result in dramatic sparing of either one or both optic pathways while maintaining high doses to tumor.

The results of the present study using IMRT compare favorably with older series analyzing outcomes for patients treated for sinonasal malignancies using conventional and three-dimensional planning systems. Blanco *et al.* (20) reported 5-year rates of local control and overall survival of 58% and 27%, respectively, among 106 patients treated with radiation therapy using primarily conventional techniques at Washington University. Similarly, Katz *et al.* (5) reported 5-year local control and overall survival rates of 60% and 50%, respectively, for 78 patients treated with conventional techniques. Using three-dimensional conformal techniques, Roa *et al.* (21) reported 5-year rates of local control and overall survival of 65% and 60%, respectively, among 24 patients treated in the postoperative setting at the University of Michigan. Notably, attempting to draw comparisons between respective series is complicated by the wide variability in surgical and radiation techniques employed across institutions. Moreover, heterogeneity with respect to tumor histology and primary sites of disease also makes interpreting conclusions difficult.

Despite these variations in patient selection and therapeutic strategy, it is notable that nearly all previous studies analyzing patient outcome after radiation therapy for sinonasal cancers have reported a high rate of complications. Takeda *et al.* (7) reported a 25% incidence of radiation retinopathy and a 7% incidence of neovascular glaucoma among 25 patients treated with conventional radiation therapy for malignancies of the nasal cavity and paranasal cavity. Katz *et al.* (5) similarly reported that 21 of 78 patients developed unilateral blindness and 5 patients de-

veloped bilateral blindness with conventional techniques (5). In addition, Meyers *et al.* (22) performed neurocognitive testing on 19 patients treated with radiation therapy using conventional techniques at the M.D. Anderson Cancer Center and found that memory impairment occurred in 80% of patients and an additional one-third experienced neurocognitive difficulties with visual-motor speed, frontal lobe executive functions, and fine motor coordination. Although more recently published series using three-dimensional conformal techniques reveal that complication rates have diminished with more sophisticated planning, the reported incidence is still significant. With a median follow-up of 19 months, Pommier *et al.* (23) reported 2 cases of cataracts and 1 patient who developed blindness among 40 patients treated for sinonasal tumors with three-dimensional conformal radiation therapy. In comparison, the incidence of serious visual deficits in the present study was minimal. Other complications, which have been previously reported but that we did not observe, include radionecrosis of bone, meningitis, and brain necrosis (4).

The only other study, to our knowledge, reporting on patient outcome after IMRT for the treatment of malignancies of the paranasal sinuses was recently reported from Ghent University Hospital in Belgium. Duthoy *et al.* (24) reported 4-year local control and overall survival rates of 68% and 59%, respectively, among 39 patients treated with IMRT in the postoperative setting. Similar to our results, they reported acceptable toxicity with a median follow-up of 31 months. Chronic toxicity, as evaluated prospectively, included visual impairment in 5 of 33 evaluable patients with no cases of blindness. Notably, 2 of these patients did not have any clinical symptoms but were diagnosed with optic neuropathy based exclusively on ophthalmologic examination using funduscopy, visual evoked potentials, and perimetry.

Our finding that most failures occurred within the high-dose region is consistent with published reports analyzing results of IMRT for other head-and-neck disease sites (25–27). Because the possibility of geographic miss has always been a concern when IMRT is used, that there were no

marginal failures suggests that our definition of target volumes is adequate. Nevertheless, the relatively low rates of local control within the high-dose regions indicate that studies investigating the potential utility of dose escalation may be of particular importance in the future and lead to further refinements in target volume definitions. From a dosimetric standpoint, it is also of interest that in regions where the CTV and critical structures potentially overlap, an underdosage of CTV was frequently tolerated to fulfill the constraints for the optic structures. Although we were unable to ascertain the clinical repercussions of this phenomenon, questions persist regarding the optimal target volume delineation in this setting. Last, the role of neck irradiation remains controversial in the management of sinonasal tumors. Although there were no regional failures observed in the present series despite the fact that less than one-quarter of the patients received elective neck irradiation, others have suggested that the risk of subclinical involvement in the neck is sufficiently high to warrant treatment in certain cases (28). Our current policy regarding elective neck irradiation is to evaluate each case on an individual basis, carefully considering the extensiveness and lymphatic draining of the primary tumor.

Although the results of the present study are encouraging, we assert that additional follow-up is needed before definitive conclusions can be reached. Radiation-induced neuropathy has been reported as late as 14 years after completion of treatment (7). The primary limitation of this retrospective study was that we were unable to perform formal ophthalmologic and neurocognitive testing to possibly detect subclinical injury. However, with relatively mature follow-up, it is reassuring that no patient developed overt clinical signs of radiation injury after treatment with IMRT. In conclusion, these clinical data validate the results of previous dosimetric studies demonstrating the feasibility of IMRT to improve outcome for patients with cancers of the nasal cavity and paranasal sinuses. Further studies investigating the use of IMRT, possibly in conjunction with chemotherapy, should be pursued in the future.

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