Original Article

Prospective Assessment of Outcomes in 411 Patients Treated With Hyperbaric Oxygen for Chronic Radiation Tissue Injury

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BACKGROUND: Although hyperbaric oxygen is used to treat chronic radiation tissue injury, clinical evidence supporting its efficacy has been limited to date. The authors report prospectively collected patient outcomes from a single center's large experience using hyperbaric oxygen to treat chronic radiation injury. **METHODS:** Since 2002, patient outcomes at the conclusion of a course of hyperbaric oxygen treatment for chronic radiation tissue injury at Virginia Mason Medical Center in Seattle have been graded by a board-certified hyperbaric physician and prospectively recorded. From 2002 to 2010, a total of 525 patients received treatment for 1 of 6 forms of radionecrosis analyzed. After excluding 114 patients for incomplete records or treatment courses or for previous receipt of hyperbaric oxygen therapy, records of 411 patients were retrospectively reviewed in 2010, and outcomes were regraded by a second board-certified physician. A positive clinical response was defined as an outcome graded as either "resolved" (90%-100% improved) or "significantly improved" (50%-89% improved). **RESULTS:** A positive outcome from hyperbaric treatment occurred in 94% of patients with osteoradionecrosis of the jaw (n = 43), 76% of patients with cutaneous radionecrosis that caused open wounds (n = 58), 82% of patients with laryngeal radionecrosis (n = 27), 89% of patients with radiation cystitis (n = 44), 63% of patients with gastrointestinal radionecrosis (n = 73), and 100% of patients who were treated in conjunction with oral surgery in a previously irradiated jaw (n = 166). **CONCLUSIONS:** The outcomes of 411 patients collected prospectively over 8 years strongly supported the efficacy of hyperbaric oxygen treatment for the 6 conditions evaluated. The response rates previously reported in numerous small series were supported by the responses achieved in this large, single-center experience. ***Cancer*** **2012;118:3860-8.** © *2011 American Cancer Society.*

KEYWORDS: radionecrosis, osteoradionecrosis, hyperbaric, oxygen, treatment.

INTRODUCTION

Hyperbaric oxygen (HBO_2) therapy often is used clinically to treat various forms of chronic radiation tissue injury.[1,2] It is known that radiation therapy induces an endarteritis in normal tissues that also are exposed to ionization within the therapeutic field.[1] The resultant capillary loss leads to the development of a hypoperfused, hypoxic, hypocellular state in previously irradiated tissue. It was believed traditionally that this was the primary mechanism of chronic tissue radiation injury. More recently, the radiation oncology community has emphasized the concept of the fibroatrophic effect as a key pathophysiologic process in the development of delayed radiation injury.[3,4]

Tissue fibrosis has always been recognized as an important component of delayed radiation injury. The fibroatrophic model is supported by the cellular depletion and exuberant fibrosis that can be appreciated easily either clinically or with light microscopy of tissue samples taken from patients or experimental animals. Several cytokines that contribute to this process have been identified, the best studied of which is transforming growth factor-beta. A review of the current state of the art in understanding the biologic markers implicated in radiation injury recently was published.[5]

The spectrum of biochemical reactions leading to clinical radiation complications begins at the time of radiation exposure, although clinical expression may not be observed for months or years. The pathologic processes eventually can lead to tissue breakdown or failure to heal after injury, conditions commonly known as *soft tissue radionecrosis* (STRN) or

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osteoradionecrosis (ORN), depending on the site. Once STRN or ORN have developed, the natural history is for the lesions either to remain static and nonhealing or to worsen, but they do not improve spontaneously. Thus, spontaneous healing is rare, and there are few definitive options for the treatment of these conditions other than HBO_2.

Traditionally, the mechanism for benefit from HBO_2 in STRN and ORN has been attributed to the angiogenesis and capillary regrowth stimulated by the large plasma to tissue oxygen gradients present during HBO_2 therapy.[6,7] Recent studies suggest that mediation of the fibroblastic stromal process and also stimulation of vasculogenic stem cells may play significant roles in the clinical response of radiation injury to HBO_2.[4,8] Preclinical studies involving microscopic morphometry and functional compliance of small bowel in a murine model demonstrated a decrease in fibrosis in animals that received HBO_2 treatment.[9,10] Mobilization of stem cells after HBO_2 has also been demonstrated.[11] It has become apparent that multiple mechanisms are involved in the genesis of radiation injury.[3]

To date, clinical support for the efficacy HBO_2 as treatment for chronic radiation injury has been relatively limited. Supporting literature includes case reports; numerous, small, retrospective case series; a retrospective review of 1 center's experience treating a variety of forms of radiation necrosis[12]; 4 prospective, randomized controlled trials focused on specific bodily sites of injury[13-16]; and some systematic reviews of the topic.[17,18]

In an effort to monitor treatment outcomes at our own hyperbaric center, we have prospectively graded and recorded response to HBO_2 therapy at the conclusion of each patient's treatment course since 2002. During that time, we have treated over 500 patients for chronic radionecrosis. We report here the results of our experience treating 6 forms of radiation tissue injury, in some instances nearly equaling the cumulative experience previously published in the literature for a particular body site. The research question to be answered was the effect of a completed course of HBO_2 therapy on chronic radiation injury at each of these 6 diverse sites.

MATERIALS AND METHODS

The Virginia Mason Center for Hyperbaric Medicine in Seattle has been a regional referral center for HBO_2 therapy since it was founded in 1969. The facility's original multiplace chamber, which is capable of treating a maximum of 4 patients simultaneously, was replaced in 2005 with the current triple-lock, multiplace system, which measures 10 feet 2 inches in diameter and 46 feet long and is capable of treating up to 18 patients simultaneously.

Patients treated in the facility must have an indication recommended by the Undersea and Hyperbaric Medical Society (UHMS)[2] and approved by Medicare[19] for hyperbaric therapy. Among those conditions is chronic radiation tissue injury, manifest as "soft tissue radionecrosis" or "osteoradionecrosis," the terms used by Medicare and most third-party insurance carriers to classify late radiation injury for reimbursement. Patients who received treatment for chronic radiation injury with primary intent to heal typically received initial courses of therapy involving 30 treatments until about 2004, at which time 40 treatments became the specialty standard because of an impression among experts that healing was enhanced and durability was greater when 40 treatments were administered. Each HBO_2 treatment comprises approximately 2 hours of pressurization to 2.36 absolute atmospheric pressure with 90 minutes of 100% oxygen breathing at maximum pressure. Patients with STRN who have healed incompletely after 40 treatments may have their course extended to a maximum of 60 total treatments according to UHMS guidelines.[2] Patients who receive treatment before dental extractions or for established ORN are treated according to protocol and receive either 20 preoperative and 10 postoperative treatments or 30 preoperative and 10 postoperative treatments, respectively.

With regard to general patient management, individuals with these conditions are offered treatment from 5 times weekly (once daily Monday to Friday) to 11 times weekly (twice daily Monday through Friday and once daily on Saturday), at their discretion. In our experience, the median number of treatments for such patients is 5 per week.[20] All patients undergo nutritional screening with subsequent dietary counseling, as appropriate. Those who smoke cigarettes at the time of referral are encouraged to stop, but hyperbaric therapy is not withheld if they continue to smoke. Neither pentoxiphylline nor vitamin E is added to the pharmacologic regimens of any patients during their course of hyperbaric treatment. The most recent thoracic imaging study available is reviewed at the initial consultation visit, and patients with macrobullous lung disease are declined for therapy. Active malignancy is not considered a contraindication to hyperbaric exposure, but those with treatable disease typically

are encouraged to pursue such treatment before hyperbaric treatment. Therefore, the only individuals knowingly treated with malignancy are those with terminal disease who have symptoms from their radiation injury that are sufficiently severe to justify the multiple-week course of therapy.

Since 2002, the medical record of each patient discharged after a course of hyperbaric treatment has been reviewed by a facility physician who is board-certified in Undersea and Hyperbaric Medicine, and outcomes at the time of completion of therapy have been assessed and recorded. In addition to progress documented in the medical record, patient interviews at the time of discharge and the results of follow-up evaluation by the referring physician, when available, are incorporated into formulating the outcome assessment. Patient interviews are performed on the day of the last scheduled hyperbaric treatment, when it is anticipated that the patient will not be returning for further therapy.

Outcomes are graded as 1) resolved (90%-100% improved), 2) significantly improved (50%-89% improved), 3) improved (0%-49% improved), 4) unchanged (0% improved), or 5) worse. The percentages are estimated in discussion with the patient when reviewing the treatment course and include both objective findings as well as the patient's subjective estimation of symptom improvement with the course of therapy. A positive response to therapy is 1 that falls into the first or second outcome category (resolved or significantly improved). Some of the responses, by their nature, are largely subjective estimates by the patient. In the case of laryngeal radionecrosis, for example, the endpoints of treatment often are improvement in symptoms like dysphagia, odynophagia, xerostomia, and dyspnea. If a patient reports 75% improvement and objective evidence is not contradictory, then that outcome will be the number recorded. In the case of dental extraction from irradiated jaw bone, the patient is graded as "resolved" if all gingival soft tissues are healed at the end of the postoperative course; "improved" if the tooth extraction is successful but a small area of gingiva remains unhealed; "unchanged" if the tooth has been extracted but an equally large gingival defect persists, resulting in no net benefit; and "worse" if exposed bone is apparent at the end of the postoperative hyperbaric course.

After we obtained approval from the Institutional Review Board of Virginia Mason Medical Center, the records of patients who received treatment for 1 of 6 forms of chronic radiation tissue injury from 2002 to 2010 were rereviewed in 2010 by a second physician who also was board-certified in Hyperbaric Medicine to confirm diagnosis and treatment details, and to independently grade outcome. This physician was not involved in either the initial outcome scoring or care of the patients reviewed. The outcomes scored by each physician were compared; and, when they did not agree, the aspects of the case were discussed between them, and a mutually agreeable outcome score was determined.

Forms of radiation tissue injury that were selected for evaluation in this report included 1) dental extractions (or other oral surgical procedures involving jaw bone) within a previously irradiated field, 2) established ORN of the jaw, 3) STRN of the larynx, 4) STRN of the bladder (radiation cystitis), 5) STRN of the bowel (radiation proctitis or enteritis), and 6) STRN of the skin with cutaneous wounds. To avoid the confusion that would be caused by detailed listings of the specific types of problems suffered by each patient within these 6 subgroups, injuries within that organ or site were combined for this analysis. For example, STRN of the bladder included any of the manifestations from which the patient may have been symptomatic—hemorrhage, pain, frequency, urgency, fistula formation, incontinence, obstruction, etc. The response rates reported encompassed the constellation of complications suffered by an individual patient. More detailed information on the response of specific complications to hyperbaric treatment is available in some of our other organ-specific publications.[20-24]

Because this was an observational case series and not a randomized controlled trial, in addition to our research question regarding the effects of a completed course of HBO_2 therapy on various forms of chronic radiation tissue injury, a per-protocol analysis was applied. Patients who were excluded from this analysis were those with a history of prior HBO_2 treatment, those whose medical records were insufficiently complete to allow retrospective outcome scoring, and those who did not complete their prescribed course of hyperbaric therapy.

To compare the results using our outcome scoring system with a standard staging system for 1 form of chronic radiation tissue injury, we chose STRN of the larynx and attempted to retrospectively categorize patients who received treatment for that condition before and after hyperbaric therapy by chart review using the Chandler system (Table 1).[25] Sufficient data were recorded in the medical record to allow Chandler grading of 20 patients, and the results were compared with those from our usual system.

RESULTS

In total, 525 patients received HBO_2 treatment from 2002 to 2010 for 1 of the 6 categories of radiation tissue injury described in Table 2. Exclusions included 32 patients who had received prior HBO_2, 19 patients who had incomplete medical records, and 63 who had incomplete courses of therapy. After excluding 114 patients, the study population included 411 patients with diagnoses distributed as listed in Table 2. A secondary retrospective review in 2010 changed the outcome score in 7 of 411 patients, and all 7 scored lower retrospectively.

For the total study group, 243 patients (59%) resolved with hyperbaric treatment, 115 patients (28%) improved from 50% to 90%, 28 patients (7%) improved <50%, and 24 patients (6%) had no improvement. No patient's condition worsened during their course of therapy. With a positive response to treatment is defined as >50% improvement, 87% of evaluable patients demonstrated at least a short-term response to HBO_2 treatment. Response rates for each of the 6 categories of radiation injury studied are detailed in Figure 1. Rates of significant response or total resolution for individual conditions ranged from 66% for STRN of the bowel to 100% for dental extractions from or surgery on a previously irradiated jaw.

Evaluable patients received an average of 37 ± 9 hyperbaric treatments (mean ± standard deviation; range, 19-60 treatments), whereas excluded patients received 14 ± 8 treatments (range, 1-29 treatments; $P < .0001$) (Table 3). Treatment experience by category of radiation injury also is itemized in Table 3.

For patients with STRN of the larynx, Chandler grading before and after hyperbaric treatment was performed retrospectively on 20 patients. Of the 6 patients who began with a Chandler grade of 4, 1 patient completed therapy with a Chandler grade of 4, 1 patient completed therapy with a grade of 3, and 4 patients completed therapy with a grade of 2. Of 12 patients who began with a Chandler grade of 3, 5 patients completed therapy with a Chandler grade of 2, 6 patients completed therapy with a grade of 1, and 1 patient completed therapy with a grade of 0. A single patient who began therapy with a Chandler grade of 2 completed therapy with a grade of 1.

With regard to complications, treatment was quite safe for these patients. Hyperbaric oxygen therapy can be associated with confinement anxiety, but the size of our chamber makes that quite rare. When it occurred, it was managed with a small dose of anxiolytic premedication. Patients who had difficulty equalizing middle ear pressure during therapy were treated with temporary tympanostomy tube placement if needed. In our unpublished experience, this is necessary in approximately 5% of patients who are treated for these conditions. Also, approximately

Table 1. The Chandler Grading System for Laryngeal Radionecrosis[a]

Grade 1	
Symptoms	Slight hoarseness, slight mucosal dryness
Signs	Slight edema, telangiectasias
Grade 2	
Symptoms	Moderate hoarseness, moderate mucosal dryness
Signs	Slight impairment of vocal cord mobility, moderate cord edema and erythema
Grade 3	
Symptoms	Severe hoarseness with dyspnea, moderate odynophagia and dysphagia
Signs	Severe impairment of vocal cord mobility or fixation of 1 cord, marked edema, skin changes
Grade 4	
Symptoms	Respiratory distress, severe pain, severe odynophagia, weight loss, dehydration
Signs	Fistula, fetor oris, fixation of skin to larynx, laryngeal obstruction and edema occluding airway, fever

[a] See Chandler 1979.[25]

Table 2. Details of the Study Population

Diagnosis	Patients Treated	Previous HBO_2	No. of Patients: Incomplete Records	Incomplete Course	Excluded From Analysis	Evaluable Patients
Extractions/procedures in irradiated jaws	210	21	3	20	44	166
ORN jaw	62	6	5	8	19	43
STRN larynx	38	1	3	7	11	27
STRN bladder	54	2	1	7	10	44
STRN bowel	88	0	4	11	15	73
STRN cutaneous wounds	73	2	3	10	15	58
All categories	525	32	19	63	112	411

Abbreviations: HBO_2, hyperbaric oxygen; ORN, osteoradionecrosis; STRN soft tissue radionecrosis.

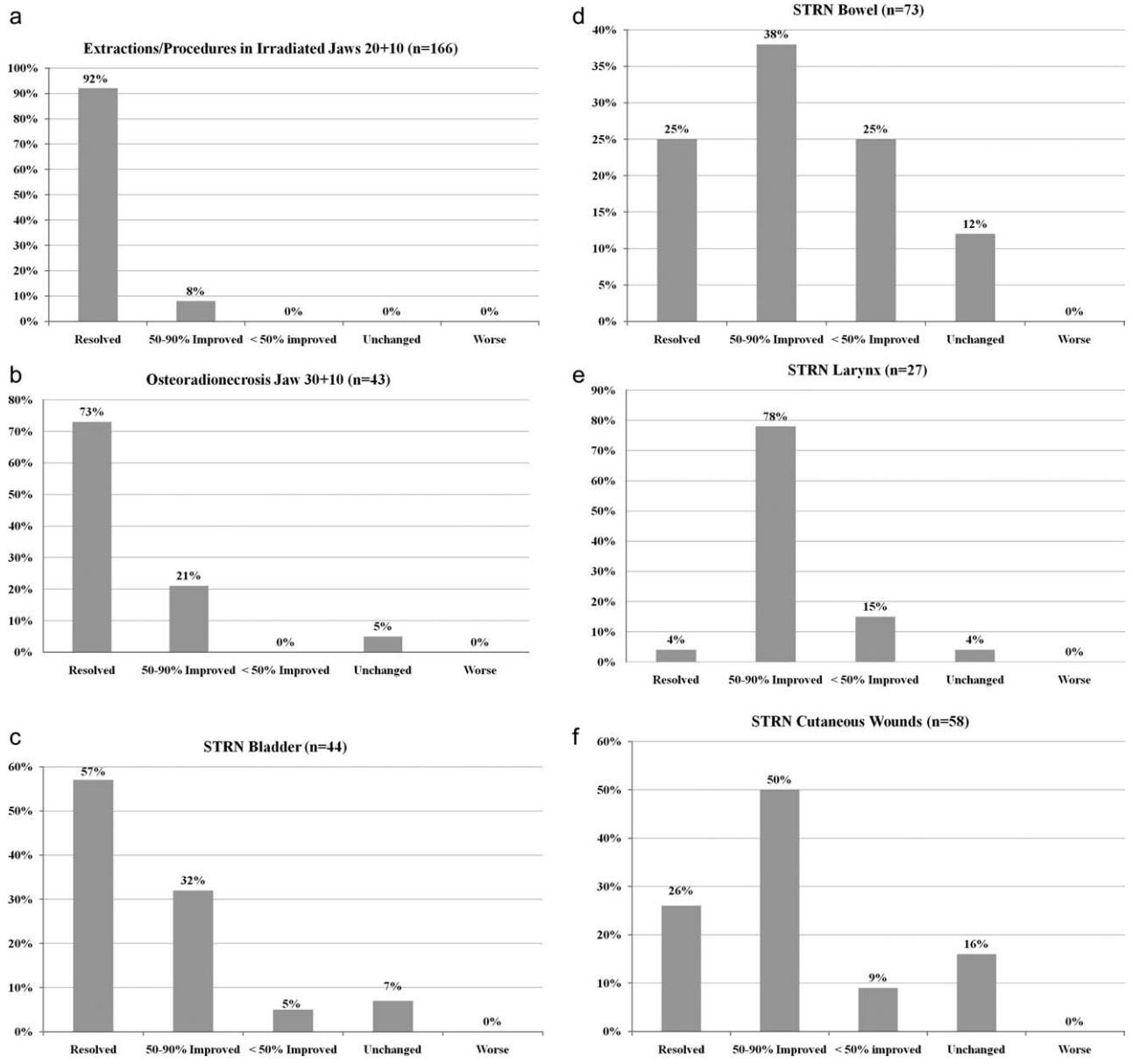

Figure 1. Outcomes after treatment with hyperbaric oxygen are illustrated for 6 forms of chronic radiation tissue injury. STRN indicates soft tissue radionecrosis.

11% of patients complain of symptomatic oxygen-induced myopia at the conclusion of therapy, a side effect we believe is generally spontaneously reversible with time. Neither claustrophobia, ear clearing problems, nor myopia caused any patients to stop therapy prematurely.

The infrequent but more significant complication of treatment, central nervous system oxygen toxicity manifest as seizure activity while breathing HBO_2, occurred in 2 patients who were receiving treatment for 1 of the 6 categories of chronic tissue radiation injury reported in this study. In 2004, a patient who was receiving hyperbaric therapy in conjunction with extractions from an irradiated jaw had a seizure on his fifth treatment. He continued therapy and completed his 30-treatment protocol without further complication or sequelae. However, he was not included in the final analysis, because he had a history of prior HBO_2 treatment, which was a pre-established criterion for exclusion. In 2005, a patient who was receiving treatment for soft tissue radiation necrosis of the bladder had a seizure on her second treatment. She continued

Table 3. The Number of Hyperbaric Treatments for Patients Included in the Analysis and for Patients Excluded for Incomplete Treatment Course

Diagnosis	No. of Hyperbaric Treatments: Mean±SD (Range)	
	Patients Included in the Analysis	Patients Excluded for Incomplete Course
Extractions/procedures in irradiated jaws	30±3 (23-40)	18±4 (6-20)
ORN jaw	40±5 (30-60)	8±8 (1-29)
STRN larynx	40±5 (28-60)	10±9 (1-24)
STRN bladder	42±6 (34-60)	14±7 (1-20)
STRN bowel	42±9 (26-60)	14±9 (1-24)
STRN cutaneous wounds	40±1 (19-60)	6±6 (1-16)
All categories	37±9 (19-60)	14±8 (1-29)

Abbreviations: ORN, osteoradionecrosis; SD, standard deviation; STRN soft tissue radionecrosis.

therapy, completed 15 additional treatments without incident, and then stopped therapy after 17 total treatments for unrelated reasons. She also was excluded from the final group of 411 analyzed in this study because of an inadequate course of therapy for outcome assessment. Thus, none of the 411 patients whose outcomes are reported here experienced central nervous oxygen toxicity. Combined, these 411 patients completed 15,099 total hyperbaric treatments.

Sixty-three of 525 patients were excluded for failure to complete their prescribed course of therapy, as noted above. The majority of our patients were referred from outside our medical center for hyperbaric treatment. For some patients, the logistics of travel alone made it difficult to complete their course of therapy. Other patients had progression of the underlying disease or a new, unrelated medical illness, resulting in disability of a severity that precluded regular travel to our medical center for hyperbaric therapy. Eventual outcome of their radiation necrosis after HBO_2 rarely was known.

DISCUSSION

HBO_2 therapy is accepted as effective treatment for chronic radiation tissue injury by such entities as the Undersea and Hyperbaric Medical Society[2] and the Centers for Medicare and Medicaid Services.[19] Clinical support for the efficacy of HBO_2 therapy in chronic radiation tissue injury largely has been based to date on case reports or on small, retrospective, single-center case series that described 1 facility's experience treating 1 form of radiation injury in a limited number of patients, as discussed above. A systematic review that was published in 2002 summed available results to that point in time and graded the existing evidence to support hyperbaric treatment of radiation injury at various sites in the body.[17] Of the 71 studies that were reviewed, all but 7 were positive for HBO_2 treatment.

Unfortunately, reporting of single cases and small case series can be strongly associated with publication bias[26,27]—the tendency for researchers and editors to handle the reporting of experimental results that are *positive* differently from those that are *negative*. The effect of this is that published series may not be truly representative of all clinical experience. Those undertaking systematic reviews must try to take publication bias into account when identifying studies for inclusion in the review. This is not simple, because it may involve searching for unpublished studies to compare outcomes. However, if this is not done, then the bias toward positive outcomes is carried forward into the review, and the summed evidence becomes overly favorable toward the therapy being evaluated.

Other published clinical evidence supporting HBO_2 treatment of chronic radiation tissue injury includes a 2004 report in which the investigators sought to report outcomes on all patients who received HBO_2 treatment for radiation-related problems at their institution from 1998 to 2003.[12] Over that 5-year period, 105 patients were treated for various forms of chronic radiation injury. Because the study was retrospective and the investigators were unable to contact 30 of the 105 patients, the group eligible for review numbered 75 patients (71%). Of those, only 43% of the total treated was willing to participate. Among those 45 patients, there were 108 sites of radiation injury, and improvement with HBO_2 was observed at 47 of those sites (44%). The value of these data is difficult to ascertain because of the low follow-up rate and small numbers, especially when they are broken down for subgroup analysis.

Four prospective, randomized clinical trials have been published in this area. A 1985 study demonstrated the benefit of adjunctive HBO_2 in the prevention of ORN when performing extractions from irradiated jaws.[13] More recently, a prospective, double-blind, sham-controlled clinical trial was reported that tested the efficacy of HBO_2 for STRN of the rectum.[15] That trial clearly demonstrated the benefit of HBO_2 in terms of both clinical outcome and quality of life. In that study, 89% of patients in the treatment arm had a positive clinical response compared with 62% in the control arm.

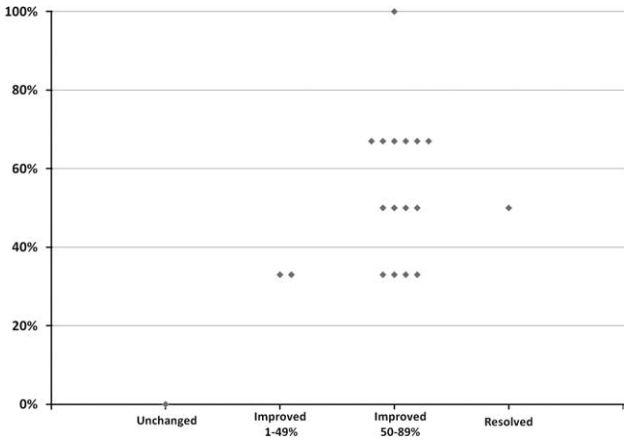

Figure 2. This is a graphic comparison of outcomes among patients who had soft tissue radionecrosis (STRN) of the larynx. The outcome assessment system used in this study is compared with the percentage decrease in the number of Chandler grades occurring with treatment. For example, a patient with initial Chandler grade 4 and final Chandler grade 2 would be represented as 50% improved toward normal.

Table 4. Comparison of Outcomes Treating Chronic Radiation Tissue Injury With Hyperbaric Oxygen From a Single Institution's Large Experience Versus the Addition of a Number of Case Reports and Small Series

	No. of Patients (%)	
Diagnosis	Single Center: VMMC[a]	Summation of Small Reports: Feldmeier & Hampson 2002[17]
Mandibular ORN	43 (94)	429 (86)
STRN cutaneous	58 (76)	133 (88)
STRN larynx	27 (82)	35 (83)
STRN bladder	44 (89)	77 (82)
STRN bowel	73 (63)	114 (55)

Abbreviations: ORN, osteoradionecrosis; STRN soft tissue radionecrosis; VMMC, Virginia Mason Medical Center.
[a] Current series.

Conversely, 2 trials performed by 1 group of investigators demonstrated no benefit from HBO_2 treatment for either brachial plexopathy or arm lymphedema in women after primary surgery and adjunctive radiation therapy for early stage breast cancer.[14,16]

Because it is believed that the mechanism of radiation injury and the therapeutic effect of HBO_2 are similar throughout the body, it seems reasonable to assume that the beneficial effect observed in rectal radionecrosis would be translated to other bodily sites of radiation injury. The current data suggest that this indeed is the case, at least for the 6 types of radiation injury studied. Obviously, some tissues or forms of injury may be more refractory, as evidenced by the described experiences with brachial plexopathy and lymphedema. Some other radiation-injured tissues with a poor response to HBO_2 treatment include spinal cord and brain.[17]

Our experience treating established ORN of the jaw included 43 patients during the period reviewed. Of these, 73% resolved, and 21% significantly improved for a 94% response rate, almost always in conjunction with surgery, as expected. The 2002 review by Feldmeier and Hampson combined 14 published series with a total of 423 patients and yielded a similar overall improvement rate of 84%.[17]

Patients with STRN of the bladder had comparably positive outcomes. Forty-four patients experienced a 57% resolution rate, and 32% had a significant improvement rate. This total 89% response rate is slightly higher than the 76% reported by Feldmeier and Hampson in 145 patients from 17 reports.[17] One reason for this may be the trend over the past decade toward treating the condition with 40 HBO_2 treatments rather than 30. In addition, patients who were treated more recently may have received earlier intervention after symptom onset, because it was reported in 2005 that treatment response was better with earlier hyperbaric treatment.[21]

It is interesting to note that, for STRN of the larynx and bowel, both our consecutive experience (n = 27 and n = 73, respectively) and Feldmeier and Hampson's collected experience (n = 37 and n = 119, respectively) indicated that more patients experience significant improvement than total resolution (Fig. 1, right column, top and middle). Nonetheless, the overall response rate for STRN of the larynx was 82% versus 84% when comparing our experience with that of Feldmeier and Hampson and 63% versus 55% for all sites of bowel injury combined.

Although our system for outcome scoring improvement with treatment in these patients is novel, we have used it with success in several other reports.[20-24] In Figure 2, improvement using our system to evaluate outcome for 20 patients with STRN of the larynx is compared with the degree of improvement using the Chandler grading system.[25] A positive relation between the 2 is apparent. In an earlier report on the treatment of soft tissue radiation necrosis of the bladder, a 79% clinical response rate was observed in the 57 patients reported.[22] When a subgroup of 22 patients underwent repeat cystoscopic examination after the completion of hyperbaric therapy, a 77% response rate was demonstrated, again supporting the validity of our outcome grading system.

Limitations to both our data and the numerous case series published include that none included controls, and

some of the outcome measures were subjective. In addition, all of our response rates were assessed at the time hyperbaric treatment was completed and do not account for any possible additional improvement or deterioration after discharge. In our experience, some patients with radionecrosis continue to heal even after stopping hyperbaric therapy if a significant improvement is attained during the course of treatment. Because our patient referral base is so large (5-state region) and the majority of patients are referred from outside our institution, it was impossible to achieve long-term follow-up on sufficient numbers to make valid conclusions about the long-term durability of healing.

The concept of publication bias toward reports with positive outcomes is discussed above. It does not appear to have been present in the 71 reports that were included in the systematic review by Feldmeier and Hampson, because our outcomes for large numbers of patients are nearly identical in most instances (Table 4).

In summary, the outcomes of 411 prospectively collected patients in this study over 8 years strongly support the efficacy of hyperbaric oxygen treatment for the 6 conditions evaluated. The high response rates observed in numerous small series collected in a systematic review are supported by the response rates achieved in this large, single-center experience. The finding that many of the conditions examined have response rates similar to the rate demonstrated in patients with rectal STRN in a prospective, randomized trial again supports the concept that the mechanism of radiation injury and response to hyperbaric treatment are likely to be similar in many different tissues throughout the body.

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The authors made no disclosures.

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