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● *Clinical Investigation*

A STUDY OF REPRODUCTIVE FUNCTION IN PATIENTS WITH SEMINOMA TREATED WITH RADIOTHERAPY AND ORCHIDECTOMY: (SWOG-8711)

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Purpose: The results of Southwest Oncology Group Study 8711 (Group 2B) are presented. The objective was to evaluate the natural history of sperm concentration and selected hormonal parameters in patients with testicular cancer treated with orchiectomy and radiotherapy.

Methods and Materials: Of a total of 207 patients enrolled on SWOG 8711, 53 pure seminoma patients were identified who were treated with orchiectomy and radiotherapy only. Sperm concentration, follicle-stimulating hormone (FSH) levels, and sexual satisfaction scores were the main parameters followed.

Results: A fraction of the patients were infertile prior to receiving radiotherapy. Our analysis indicates that incidental radiation dose to the remaining testicle affects time to recovery of fertility, and at an aggregate level, changes in FSH mirror changes in sperm concentration over time. This phenomenon is the same as that described in patients free from testicular cancer. These men evaluated their sexual activity as good after orchidectomy.

Conclusion: Our data support the use of clamshell-type testicular shields as a means of providing maximum protection to the remaining testicle. © **1997 Elsevier Science Inc.**

Radiotherapy, Seminoma, Semen, Follicle-stimulating hormone, Testicular injury.

INTRODUCTION

Modern treatment of testicular cancer is a true therapeutic success story in oncology. It is appropriate to be concerned about the morbidity of our current treatment programs, especially long-term morbidity. This report focuses on the effects of orchidectomy (ORC) and radiotherapy (RT) on reproductive function in 53 adult seminoma patients diagnosed as having pure seminoma and treated with ORC and RT. The major parameters followed over time were sperm concentration (SC) and follicle-stimulating hormone concentration (FSH).

A significant body of literature exists which describes the effect of radiation on the nondiseased testicle in healthy hosts or hosts having diseases that were not known to involve the testicle. Rowley *et al.* (17) used single doses of radiation from an orthovoltage unit and followed SC, FSH, luteinizing hormone, and testosterone. Sixty-seven normal "volunteer" males ages 25–52 had their testicle(s) biopsied, received doses from 0.08 to 6.40 Gy, and were followed for over 30 months. The authors concluded that plasma testosterone levels showed no significant change at any dose studied. Plasma LH increased when the dose was >0.75 Gy, then slowly returned to normal. Plasma FSH followed the same pattern but was more sensitive. Increases occurred at doses above 0.09 Gy. SC corresponded with changes seen upon biopsy at all dose levels. Spermatogonia were the most radiosensitive. All patients became at least temporarily azoospermic with doses of ≥0.78 Gy. The time to recovery was dose dependent, and all patients did eventually recover. This work will probably never be repeated, since the "volunteers" used are said to have been prisoners. It is important to

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note that all subsequent studies have used fractionated radiation.

Several papers (13, 19, 20) examined men treated for soft-tissue sarcomas or Hodgkin's disease with RT only with no obvious involvement of the testicles. The sarcoma group had 27 patients, and the testicular doses ranged from 0.01 to 25 Gy (they were measured directly in 17 and calculated in the rest). Change in serum FSH was most sensitive to RT dose. LH increased significantly only at high doses (>2 Gy). Serum testosterone concentration did not significantly change with RT dose. Time to recovery of SC was dose dependent, but seemed to be longer than that found by Rowley *et al.* (17), consistent with the suggestion by Speiser *et al.* (20) that fractionated radiation has a more profound effect than single doses.

Speiser *et al.* (20), Pedrick and Hoppe (16) and Kinsella *et al.* (13) studied Hodgkin's disease patients. Speiser *et al.* found no recovery for doses of 1.4–3 Gy in 12 patients (average number of fractions – 20) followed up to 40 months. Contrary to this, Pedrick and Hoppe found that the injury was transient in 18 patients (dose range of 0.28–1.35 Gy in 22–29 fractions). Kinsella *et al.* also reported transient changes in 17 patients (dose range of 0.06–0.7 Gy in 20–23 fractions). Four fathered normal offspring. Assuming that a normal minimum SC is 20×10^6 sperm/cc, 8 of 10 of Kinsella *et al.'s* cases were normal before RT, and 2 were azoospermic. Speiser *et al.* had four of eight patients with SC ranging from 20 to 26×10^6 sperm/cc before RT.

Hahn *et al.* (10) reported 14 seminoma patients. Five of 10 were oligospermic before RT. Aspermia was induced in 10 of 14 cases that received >0.65 Gy [doses ranged from 0.32 to 1.78 Gy measured with thermoluminescent dosimetry (TLD)]. Time to recovery was dose dependent. Fossa *et al.* (5) followed 29 patients. LH and testosterone remained within the normal range. The authors concluded that changes in FSH could not be correlated with gonadal dose (the mean dose in this study was 0.548 Gy; range 0.27–1). Further, disturbances in spermatogenesis were more likely the expression of impaired pretreatment sperm cell production and less likely related to RT. Support for this position comes from Berthelsen

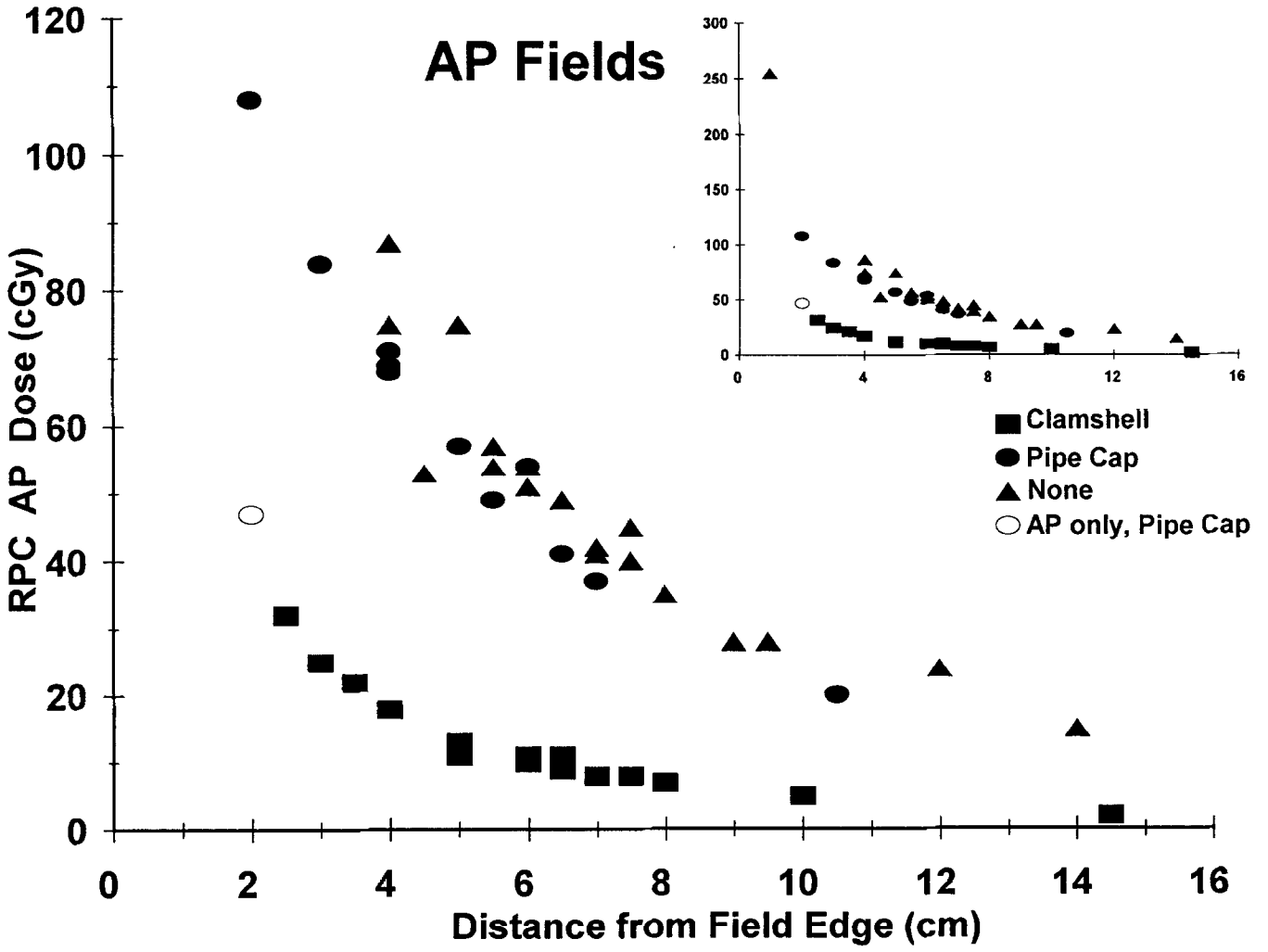

Fig. 1. RPC-calculated RT dose as a function of distance from the RT field edge: anterior to posterior projection.

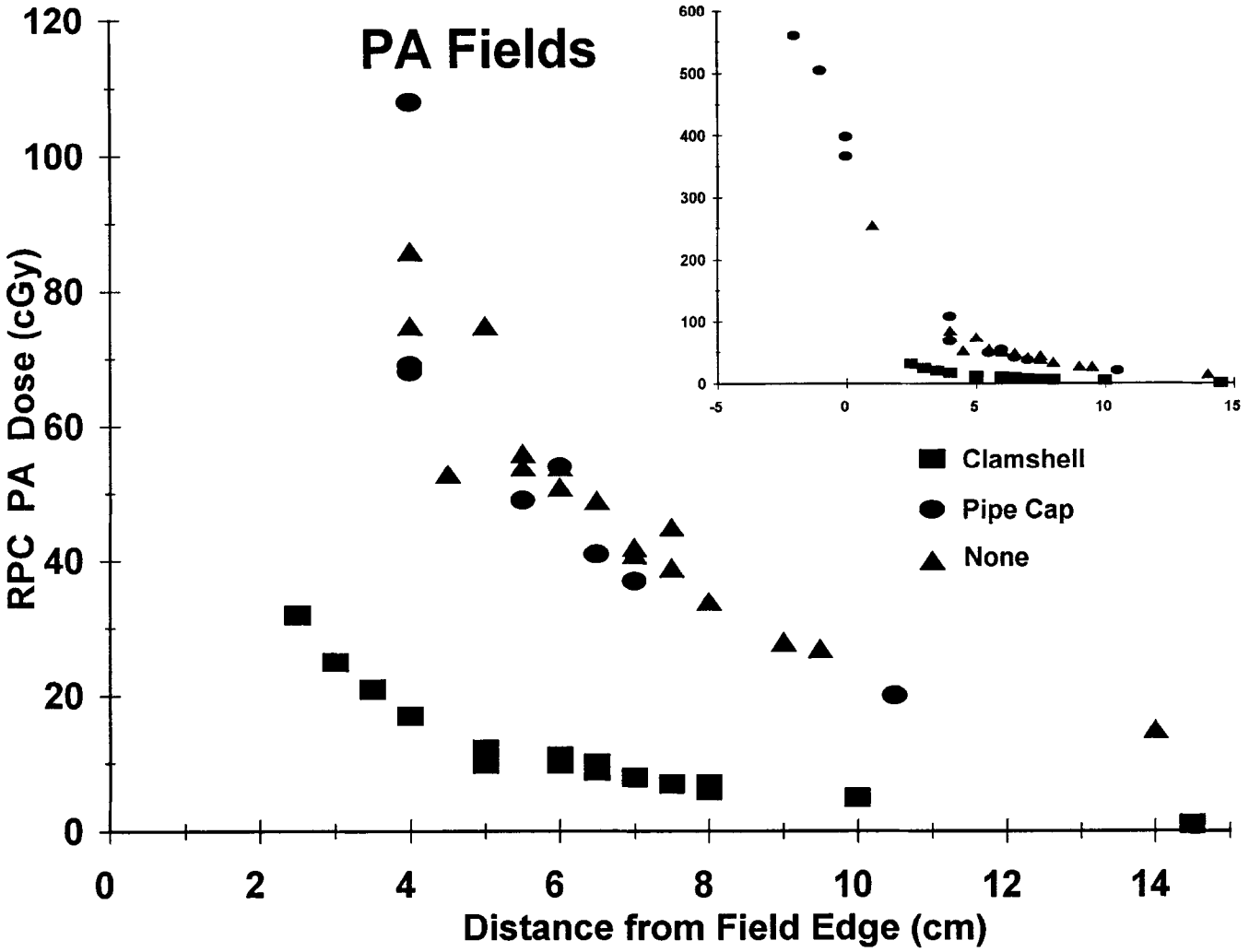

Fig. 2. RPC-calculated RT dose as a function of distance from the RT field edge: posterior to anterior projection. Note that divergence can cause the testis to be in the field.

and Skakkeback (1), who studied 218 patients prior to RT or chemotherapy in all stages and histologies. Tests included contralateral testis biopsy, semen analysis, and various hormonal studies. Biopsy showed severe and likely irreversible changes in 24% of the contralateral testis. SC was low compared to a selected reference group (17×10^6 vs. 80×10^6). FSH was uniformly elevated. LH was elevated in 12% and testosterone was low in 13%.

The Southwest Oncology Group developed Protocol SWOG 8711 with the following objectives in Group 2B (patients treated with ORC and RT only): to trace the history of semen analysis (sperm concentration) and selected hormonal parameters in testicular cancer patients treated with ORC and RT; and to trace the longitudinal effect over time of the treatment modality used on these same parameters.

SWOG 8711 presented an opportunity to follow prospectively a significantly larger number of patients than had been previously reported. We have attempted to better define the pretherapy subfertile state, the dose-dependent changes in SC and FSH, and the properties of testicular shields now in common use.

METHODS AND MATERIALS

SWOG 8711 is an observational study of five treatment groups defined by the diagnosis of testicular cancer and treatment plan. The study began on April 1, 1988, was closed on June 1, 1994, and imposed no treatment requirements. Patients were excluded if they had evidence of prior cytotoxic chemotherapy or RT; a previous retroperitoneal lymphadenectomy; or sterilization or abnormal sexual development, including cryptorchidism. A total of 207 patients were accrued. Three patients did not meet the formal criteria for eligibility: two were cryptorchid and one was registered 12 weeks post-ORC.

A total of 79 patients had pure seminomas; of these, 53 were treated with ORC and RT only, and therefore are the primary focus of this report. All patients were expected to have testing done prior to beginning RT, every 3–6

Table 1. Patient characteristics

Characteristic	*n*	Mean	SD	Median	IQR*
Age (yr)	53	34.2	6.8	33.2	30.5–38.1
RT time (days)	52	23	5	21	19–24
RT dose (Gy)	53	1.07	1.37	0.79	0.22–1.13
Stage					
1	40				
2	8				
3	2				
Missing confirmatory data	3		(all were registered as Stage 1)		
At Baseline:					
SC (10∧6 sperm/ml)	26	28.7	34.6	14.4	6.6–29.8
FSH (IU)	26	15.0	9.5	13.9	9.0–17.4
Normal SC	26	35%†			
Normal FSH	26	77%			
Normal β-HCG	51	98%			

* IQR = 25th–75th percentile.
† Percentage of *n* patients with normal SC as defined by the institution's standards of normality.

months for 5 years postregistration or until (a) they had fathered a child and had a confirmatory normal SC determination, or (b) they had two normal SC determinations. Testing included size of remaining testicle, SC, FSH, alpha-fetoprotein (AFP), β-human chorionic gonadotropin (β-HCG), and testosterone. At each follow-up visit, questions were to be asked concerning pregnancies produced and sexual satisfaction.

Early in the study, it became clear that insistence on serial SC as a requirement was inhibiting accrual. Objections of third-party payers and the logistics involved played a role. Since traditional biologic teaching and previous studies suggested that FSH changes mirrored SC changes, we elected to declare SC determination a desirable option but not a requirement for enrollment in the study.

Investigators were asked to submit their own estimates of gonadal dose. Twenty of 53 (38%) submitted measured doses using diodes or TLD. In addition, the Radiological Physics Center (RPC) in Houston, Texas, developed a procedure to calculate the dose to the remaining testicle. The procedure assumed a "standard" methodology for determining distance from the field edge to the center of the remaining testicle, because the films available did not always include enough anatomy. The same methodology was applied to all patients to assure uniformity and included calculating doses 2 cm closer and 2 cm further away to get a range of doses across the testicle. The treating institutions were asked to provide a distance from field edge to the testicle, and dose was calculated at that point as well (Figs. 1 & 2). If the testis was not shielded, doses were determined based on data from Stovall (21). Testicular shields fell into two basic categories: a clamshell type as defined by Fraass *et al.* (7) and Kubo and Shipley (14), and a pipe cap type. Unshielded doses were reduced by 10% for the pipe cap type. Doses for the clamshell type were determined based on the data of Fraass *et al.* without regard to beam energy.

Patients were asked to rate their sex lives at the time of each visit. New pregnancies and/or births were recorded.

STATISTICAL CONSIDERATIONS

Statistical analyses are based on time since ORC. All data for visits in which β-HCG levels were missing or rated above normal according to the institution's limits of normality were excluded. Baseline measurements are those taken post-ORC and prior to the start of RT.

To examine the association of SC and FSH over time by dose, we divided the patients at the median into high- and low-dose groups so that we had two similarly sized groups. We used a lowess scatterplot smoother (3, 4) to show the middle of the distribution of SC and FSH and how it changed over time. Since length of follow-up varied by subject, we restricted the sample to individuals with at least two measures, the last occurring after 1 year post-ORC. For the SC data, we divided the subsample into two groups: (a) those whose latest visit occurred after 1 year but not after 2 years post-ORC; and (b) those whose latest visit occurred after 2 years post-ORC. We restricted the data in the second subgroup to those whose latest visit occurred after 2 years post-ORC but within the first 3 years and cut the figures off at 2.5 years. This was done to eliminate bias from the fact that patients dropped out of the study at different times after the first 2 years. For the FSH data, we did not divide the subsample. We restrict the data to the first 1.5 years and cut the figures off at 1 year.

Since the laboratory facilities used by SWOG member institutions did not measure and/or report FSH in exactly the same way, we analyzed the institution values reported as normal or abnormal as well. We looked at changes in normality levels of FSH over a time period similar to the lowess curves. We selected patients with data from a first visit, a 6-month visit, and a 12-month visit. The first visit was defined as the first visit occurring in the first 3 months

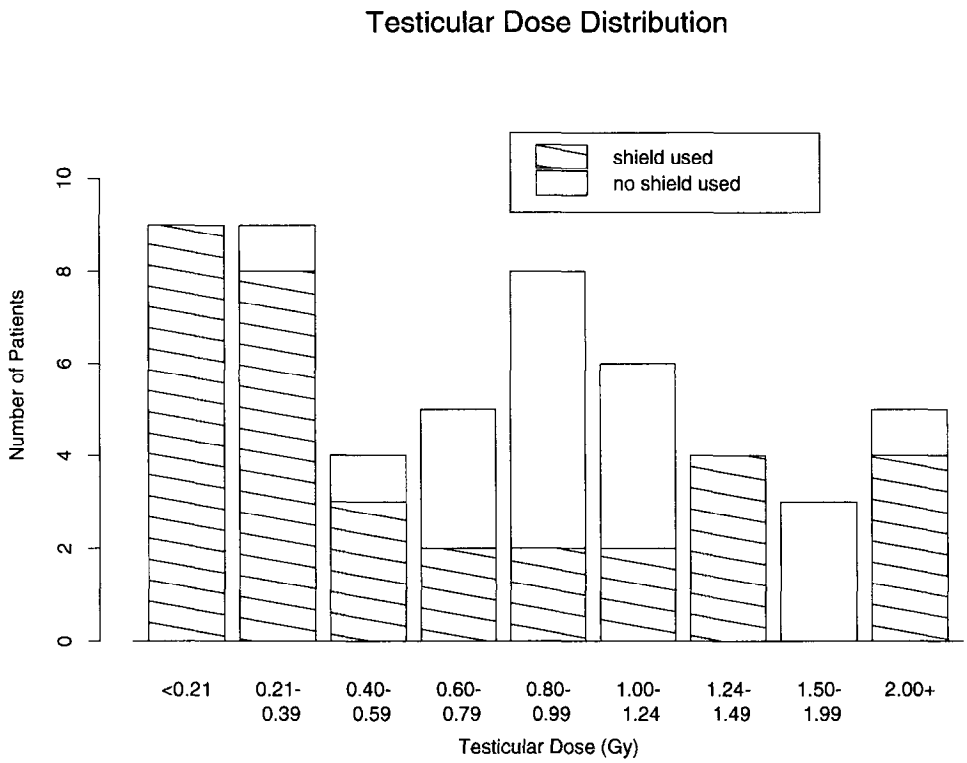

Fig. 3. Testicular RT dose distribution.

after ORC but not necessarily pre-RT; the second visit was defined as the visit closest to 6 months, occurring from 3 to 9 months; and the 12-month visit was defined as the visit closest to 12 months, occurring from 9 to 18 months. We had a slightly different subset of patients from those represented in the lowess plots, because now patients were required to have three follow-up visits and we were considering normality levels as reported by the institution rather than a continuous variable. Graphs based on normality are also presented for SC in the first year.

The following number of SC and FSH determinations were excluded due to either missing β-HCG values or values rated above normal according to the institution's limits of normality. In Fig. 5, five SC determinations are excluded owing to missing β-HCG: four in the low-dose group and one in the high-dose group. In the low-dose group, three determinations were from the same patient, who was no longer represented in the sample. The fourth determination excluded in the low-dose group and the one determination excluded in the high-dose group were both from patients who were still represented from other data. In Fig. 6, five SC determinations were excluded from the high-dose group owing to missing β-HCG levels: two determinations from two patients and one from a third. All three patients remain represented in the figure from other data. In Fig. 7, one patient in the low dose group was omitted owing to an abnormal β-HCG at baseline from both SC and FSH plots. A second patient with a low dose was omitted from the FSH plot owing to a missing β-HCG level for the 12-month visit. In Fig. 8, two FSH determinations, each from a single unique patient, were omitted from the low-dose group: one owing to a missing β-HCG value and one owing to an abnormal one. Both patients remain represented in the figure by other data.

RESULTS

The population

A total of 55 patients were originally registered to Group 2B. Two patients were ineligible for Group 2B and were omitted from this analysis: One patient did not have seminoma and one patient refused RT and was therefore followed up in the orchidectomy-only treatment group. Of the remaining 53 patients, 40 (75%) were married at the time of registration. Other patient characteristics including stage are given in Table 1. The median follow-up in the group of 53 patients was 2.1 years (maximum 5.5). Of our sample of 53 patients, 31 (58%) had at least two visits with SC and normal β-HCG when the last visit occurred after 1 year post-ORC.

Post-ORC and Pre-RT parameters

We define being fertile as having an SC of $>20 \times 10^6$ sperm/ml. Baseline data are available for 26 of the 53 patients; 14 (54%) were subfertile pre-RT. The median baseline SC for this entire group was 14.4×10^6 sperm/ml. Baseline FSH data are available for 26 patients. The median is 13.9 IU. Testosterone was normal and did not significantly change at any RT dose level over time. Sim-

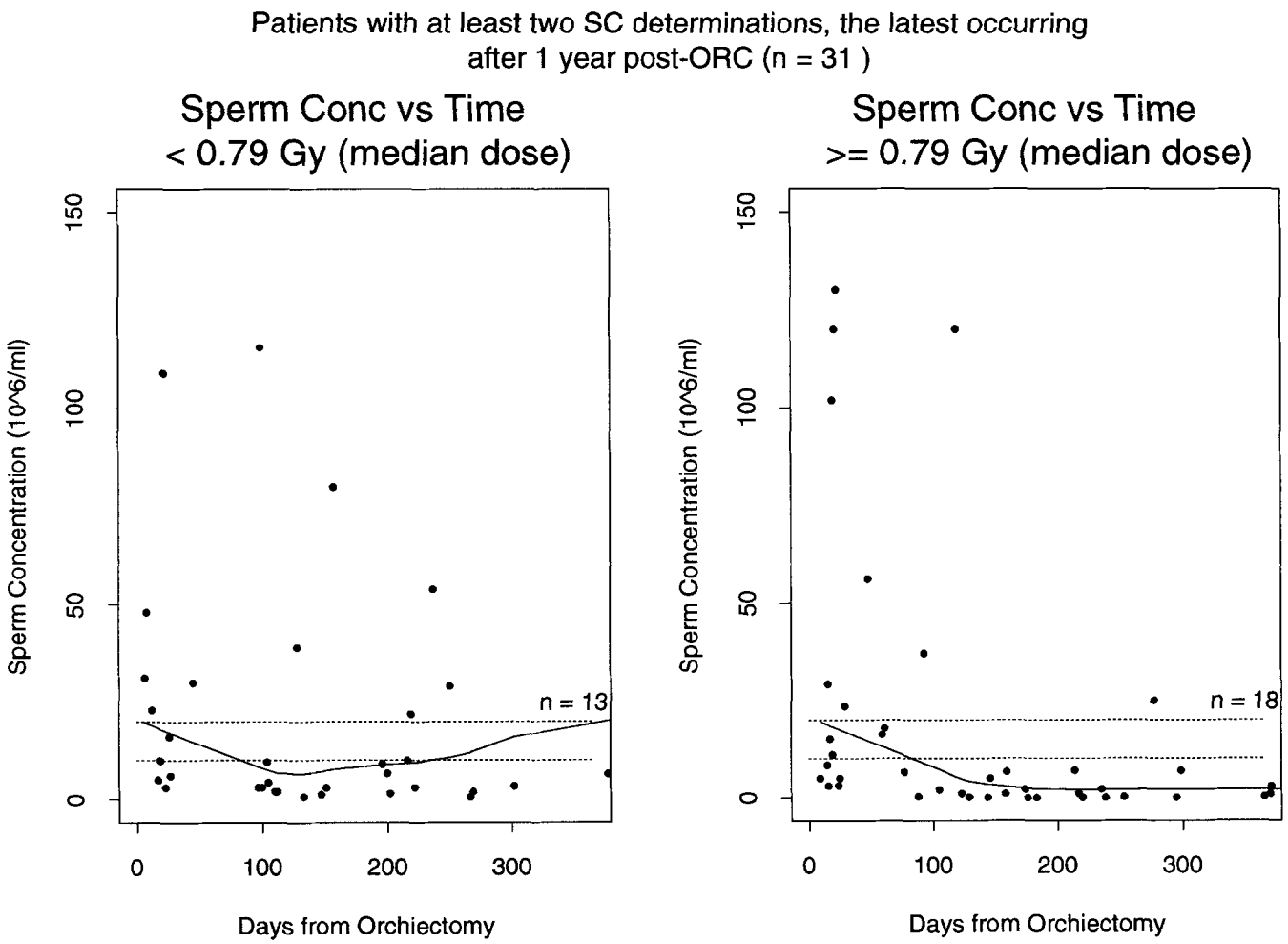

Fig. 4. SC vs. days from orchiectomy in 31 patients with at least two SC determinations, the latest occurring after 1 year post-ORC.

ilarly, clinical dimensions of the remaining testicle did not change over time.

In the entire group of 119 nonseminoma patients enrolled in SWOG 8711 who did not get RT, 36 had baseline SC and a normal β-HCG as institutionally defined. A total of 19 of the 36 (53%) were subfertile at baseline. This compares to 14 of 26 (54%) for pure seminoma patients.

RT doses, shields, and fields

The median gonadal dose was 0.79 Gy. The use of testicular shields was usually but not always associated with a low dose. Some clinicians chose not to use shields at all. For this report, we chose to group patients into a high-dose group ($\geq$0.79 Gy) vs. a low-dose group ($<$0.79 Gy). In the low-dose group, 22 of 26 patients were treated using shields. In the high-dose group, 12 of 27 were so treated (Fig. 3).

The tumor RT average dose was 26.02 Gy [standard deviation (SD) = 3.09] delivered over 23 days (SD = 4.7) at 1.67 Gy/fraction (SD = 0.18). Thus, the remaining testicle received on average 4.3% of the prescribed dose. There was nothing in our review of patient records to indicate that dose was varied systematically according to any patient characteristic we examined.

The treating institution reported measured radiation doses to the remaining testicle for 20 patients. For 12 of these patients, a clamshell-type shield was used. The average measured dose was 0.413 Gy (SD = 0.286), which corresponds to 1.6% of the dose delivered to the lymph nodes of these 12 patients on average. For four patients in whom pipe cap types of shields were used, the average measured dose was 1.4 Gy (SD = 0.402), which corresponds to 5.1% of the dose delivered to the nodes of those four patients on average. In contrast, for four patients in whom no shields were used the average measured dose was 1.148 Gy (SD = 0.259), which corresponds to 4.4% of the dose delivered to the nodes of those four patients on average.

It is possible to create a linear mathematical function that relates the calculated dose to the measured dose. The correlation coefficient was 0.86 (90% confidence interval = 0.704–0.937). A review of 47 of the 53 seminoma patients treated with RT reveals that six patients were

treated with inverted-Y fields that included all pelvic nodes. One patient received RT to the chest. On average, the cephalad border of the pelvic field was placed in the range of T11–T12.

Sperm concentration

Figure 4 presents a summary description of the SC data over time for the two RT dose groups derived from 31 patients (13 are in the low-dose group and 18 in the high-dose group) with at least two SC determinations, the last occurring after 1 year post-ORC. Figure 5 shows the curves for a group of patients followed up for 1 but not 2 years; and Fig. 6 shows the curves for the remaining group of patients followed up at least 2 years. The curve in Fig. 5 begins at a level indicating that a substantial portion of the patients in the high-dose group who were followed up for 1 but not 2 years was fertile prior to RT. Recovery of fertility occurs in approximately 1 year post-ORC in the low-dose group for those followed up <2 years, and a little later for those followed up for at least 2 years. For patients followed up at least 2 years in the high-dose group, recovery was observed on average at a little over 2 years. However, it is of interest to note that 4 of 16 patients in the high-dose group who had follow-up visits within the first 1.5 years have SC that are high enough that they are likely fertile (one of these had a fertile SC determination during RT but did not have one done post-RT). Further, examination of the raw data beyond 1.5 years shows that among those who were followed up for at least 2 years, of nine patients who have SC determinations in the first 3 years, five have values that suggest fertility in that time. The left panel of Fig. 7 displays the trends portrayed in Fig. 4 based on whether the SC fell below institutional limits of normality.

FSH

Figure 8 shows FSH values against days from ORC as a lowess curve for each dose group. Again, the sample is restricted to patients with at least two FSH values, the last occurring after 1 year post-ORC. There are 17 patients in the low-dose group and 18 in the high-dose group. The scatterplot smoothes show no difference in trend due to

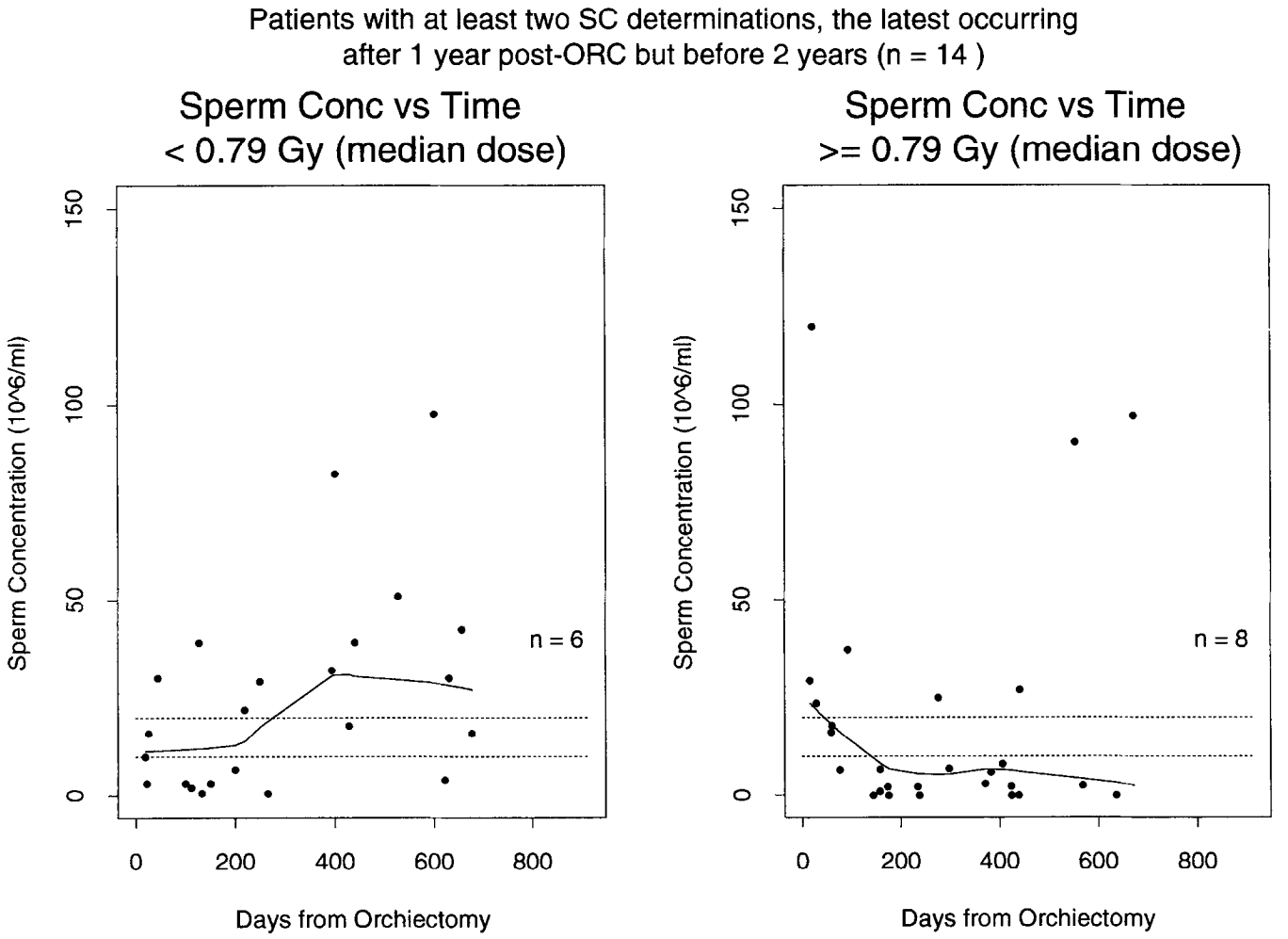

Fig. 5. SC vs. days from orchiectomy in 14 patients with at least two SC determinations, the latest occurring after 1 year post-ORC but before 2 years.

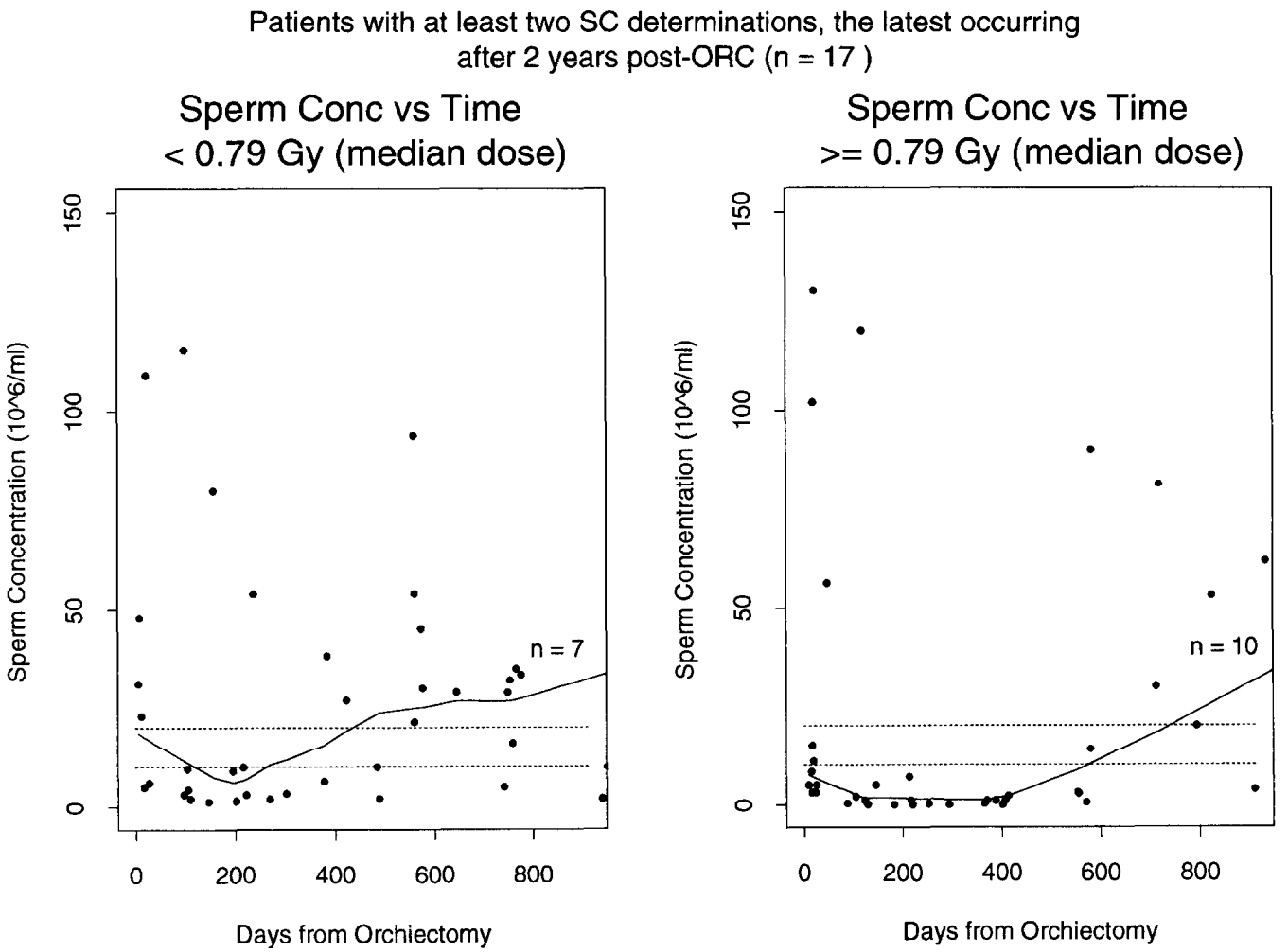

Fig. 6. SC vs. days from orchiectomy in 17 patients with at least two SC determinations, the latest occurring after 2 years post-ORC.

dose group. There is a definite increase in FSH, with the maximum occurring at about 6 months.

The right panel of Fig. 7 shows the percentage of patients with abnormally high FSH as defined by the institution's limits of normality against time. The plot shows an increase in the percentage of abnormal patients in both dose groups at approximately 6 months, and a decrease in the percentage who were abnormal in the low-dose group only at approximately 12 months. This pattern mirrors the changes in SC.

The previously published experience indicates that FSH and SC vary in a mirrored manner over time when both are tested in conjunction with reproductive capacity. However, within individual patients, we have been unable to demonstrate a statistically valid inverse correlation between them. We looked at linear trends of SC and FSH over time for each patient, average changes per month of the two variables over the first two visits only, and pairwise changes in normality ratings of SC and FSH between two visits: baseline and 6 months, and baseline and 1 year.

Reproduction and sexual satisfaction

The 53 men in this group reported 13 pregnancies, including one miscarriage and one abortion (no information is available to indicate whether the abortion was therapeutic or spontaneous) in 12 different men, which produced 11 healthy children. Thirty-five subjects remained in the study and answered the questionnaire about reproductive status 1 year after ORC (±90 days). Of the 26 who chose to answer a question about whether they had been trying to father a child for more than 6 months, 3 had. None of the 32 patients who answered the question about changes in their partner's ability to conceive knew of any. Thirty-two men answered a question asking them to rate their level of sexual satisfaction in one of nine categories ranging from 0 to 8 ("cannot be worse" to "cannot be better"); the median value was 6, or "good." At 2 years after orchiectomy (±90 days), 27 patients remained in the study and completed the same questionnaire. Of the 15 who chose to answer the question about whether they had been trying to father a child for more than 6 months, 3 had. One of the 24 patients reporting

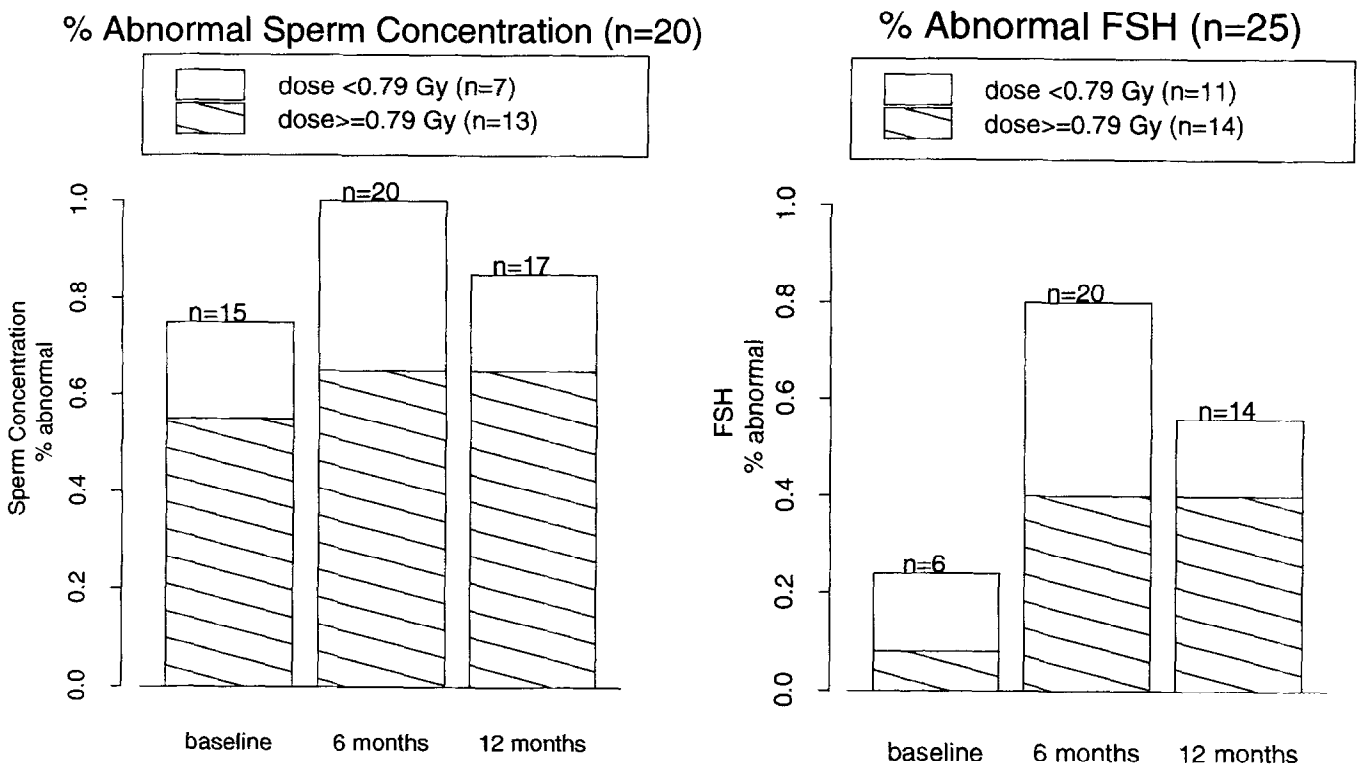

Fig. 7. Percent abnormal SC and FSH as determined by the reporting institutions vs. time after ORC.

whether there had been any change in his partner's ability to conceive reported a change. Twenty-two patients answered the question about their sexual satisfaction; the median was again 6, or "good."

DISCUSSION

Prior to beginning RT, 54% of our seminoma patients were subfertile. For the nonseminoma patients who did not receive RT enrolled in SWOG 8711, it was 53%. This is consistent with data reported by Fossa *et al.* (6) that involved 117 patients followed for 1 year and 98 for 3 years, all free from relapse. All histologies and treatments were included. In their report, after ORC but before further treatment, the SC was 14×10^6/ml as compared to 83×10^6/ml in 29 age-matched controls. Overall spermatogenesis is impaired in 60–70% of patients. Thirty-two patients received surveillance only for 1 year. Their SC increased on average (20×10^6/ml to 40×10^6/ml), but it was not statistically significant ($p = 0.39$). Eight patients followed with only surveillance for 3 years also showed a similar average nonsignificant increase. Since testicular RT dose was not provided, it is impossible to interpret their post-RT data. Thus, sperm banking should be considered if the patient is interested in producing children in the near future.

The RT doses and techniques used in this multi-institutional study are consistent with those reported in the RT literature. Hanks *et al.* (11) reported in 1992 the results of a long-term study of 387 seminoma patients from 163 facilities that established the effectiveness of RT as treatment for early-stage seminoma. Based on tables in the article by Hanks *et al.* the average radiation dose was approximately 30 Gy. In our study, it was 26.2 Gy. Further, in our study only one patient was treated above the diaphragm. The study by Hanks *et al.* did not report testicular dose. No deaths have been noted in our group of 53 patients, but there was no formal intent to actively follow these men to determine survival after they completed the study assessments.

The method used to calculate dose to the remaining testicle recognizes that there is a contribution from internal scatter from the patient, collimator scatter, as well as direct irradiation via head leakage. It is not likely that any testicular shield can reliably block the contribution of internal scatter completely. The pipe cap type has a large aperture that admits some internal scatter and collimator scatter. Two devices have been described that attempt to reduce all three contributing components. Fraass *et al.* (7) described a compact clamshell-type device that has heavy shielding to cut down head leakage and a small aperture to reduce internal and collimator scatter. Kubo and Shipley (14) designed an open-ended trough device hinged to a top cover with an overhanging lip to reduce internal and collimator scatter. These devices, especially when used with a scrotal block placed on the usual block tray, provided effective shielding. Measured data in this study indicate that adequate shields reduced testicular dose from

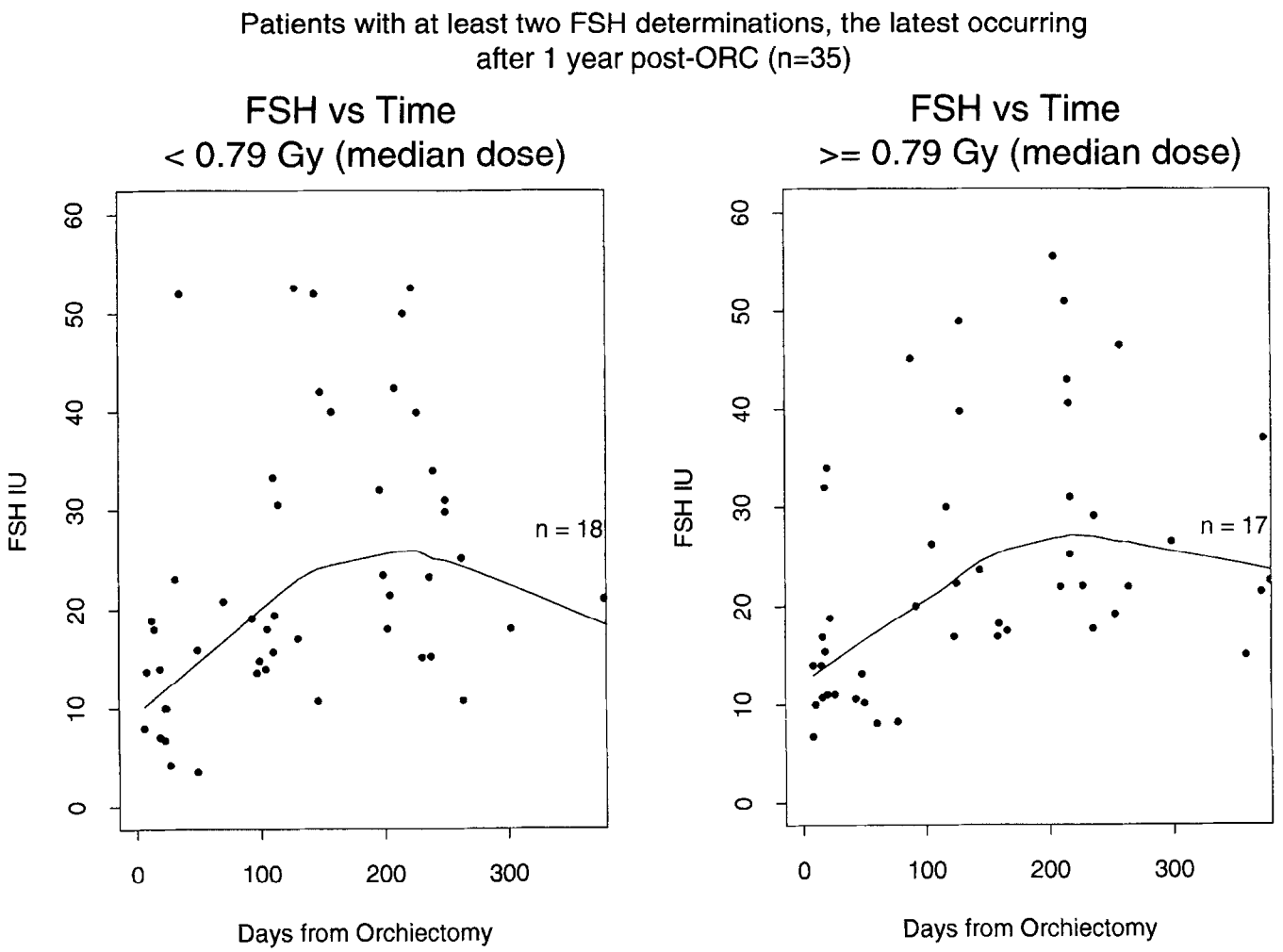

Fig. 8. FSH vs. days from orchiectomy in 35 patients with at least two FSH determinations, the latest occurring after 1 year post-ORC.

4.4% of the target dose for patients with no or pipe cap-type shields to 1.6% for patients with clamshell-type shields on average.

At the RT doses used in this study, in the aggregate SC and FSH behaved in a mirrored fashion. As one decreased, the other increased, and vice versa. In our low-RT dose group, SC returned to normal in approximately 12 months. In our high-RT dose group, the time required averaged a little over 2 years. Freund *et al.* (8) reported that six of eight patients (whose gonadal dose was 0.15–1.57 Gy) had seminal parameters that were slightly decreased or normal after 10–24 months of follow-up. Schlappack *et al.* (18) reported 11 patients and concluded that neither the time to recovery of SC nor the time to peak FSH levels correlated with RT dose (mean 0.62 Gy; range 0.34–0.95). Hansen *et al.* (12) reported data from 42 patients who had been tested 3 years after treatment. Fourteen received chemotherapy in addition to RT. The gonadal doses were measured in 17 but estimated in the others (median 1.7 Gy; range 1.2–4.8). Their statistical analysis showed that rapid recovery from azoospermia significantly correlated with young age ($\leq$25), no chemotherapy, gonadal dose of $\leq$1.3 Gy, and pretreatment SC of $\geq 315 \times 10^6$. Factors that were not significant were histology (seminoma vs. nonseminoma), stage, and descensus. Our data were insufficient to evaluate age. They do demonstrate that on average, the time needed to recover SC is influenced by RT dose.

We could not discover a mathematical formula that expressed a consistent relationship between SC and FSH for individual patients or logically defined groups of patients. This unexpected lack of a relationship was initially puzzling. Pituitary hormone levels and respective target organ output vary inversely. This relationship has been essential to our understanding of the negative feedback loop linking pituitary output to end-organ control. However, the relationship between FSH and SC is more complex and less direct.

Follicle-stimulating hormone promotes testicular production of a large number of specific proteins with roles in spermatogenesis which remain undefined. Which of these serves to interact via negative feedback and thus

regulate FSH production is unknown (9, 15). It is generally accepted that these substances affect spermatogenesis in the adult at an early stage in sperm maturation. Since in man the spermatogenic process requires approximately 2 months and epididymal maturation another 10–14 days, it is quite reasonable that SC measured at a given point in time does not reflect FSH concentration at that specific time.

Other factors probably contribute to this phenomenon. Possibilities include the following: (a) Quantitative FSH concentrations are not determined in a uniform way among the participating institutions; (b) values for SC, especially low values, are imprecise and cause substantial statistical variations; and (c) FSH behaves with a "threshold" relationship to RT dose and possibly SC as well. The mechanism that causes FSH to increase is nearly maximally stimulated at some dose below 0.8 Gy on average. The mechanism that causes FSH to return toward normal is independent of RT dose and possibly SC (at least at low values) as well. Given that time to recovery is the important parameter to an individual patient, it is disappointing that we found FSH concentration to have no demonstrable predictive power.

Our 53 patients have produced 11 healthy children so far. However, it is difficult to know how many men were really consistently trying to produce children or whether their partners were in fact fertile. They describe their level of sexual satisfaction in general as good. This level of satisfaction remained constant over the duration of this study. Centola *et al.* (2) reported eight patients (mean testicular dose 0.44 Gy; range 0.2–0.78). Three of the eight subsequently fathered healthy children. Tinkler *et al.* (22) reported an extensive study of sexual satisfaction via anonymous questionnaire. Responses were available from 137 RT patients (62% of the target population) and were compared to responses from 121 controls (35%). They reported that the patients performed less well than the controls. We suggest that patients are satisfied with their level of sexual functioning, although that level may be different from that of controls.

CONCLUSION

A substantial fraction of patients with seminoma are infertile at the time of diagnosis. Administration of RT causes a decrease in SC and an increase in FSH. Both parameters generally returned to a level approaching baseline values. Thus, permanent infertility is uncommon within the studied dose range. This overall pattern was like that seen in patients who receive RT but who do not have testicular cancer. In the aggregate, FSH increases as SC decreases. However, we were not able to create a mathematical formula connecting FSH to SC that was quantitatively accurate from one individual to another. One possible explanation is that given the time required for spermatogenesis and maturation, one cannot expect that SC measured at one point in time will reflect FSH concentration at that same time. We believe that testicular shields having the following minimum specifications will significantly reduce RT dose to the remaining testicle: (a) a clamshell type with a minimal aperture to reduce internal and collimator scatter or with an overhanging lip to block internal scatter; and (b) a heavily shielded top and a separate scrotal block (AP and PA, if possible) on the tray holder to reduce head leakage.

Within the limits imposed by the patient's anatomy, the shield should protect as much of the scrotum as possible. On average, patients for whom RT testicular dose was held below 0.8 Gy recovered SC in approximately 1 year. A large majority of patients were satisfied with their level of sexual functioning. This may reflect the fact that serum testosterone levels were not affected by doses of radiation as used in this study. This group of 53 patients produced 11 healthy offspring.

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