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MICROSCOPIC VASECTOMY REVERSAL*

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More than 300 patients undergoing microscopic vasovasostomy have been carefully studied in an effort to determine the factors which affect the recovery of fertility after an accurate microscopic reanastomosis. The over-all pregnancy rate in an unselected group of early patients was 71%. Recovery of fertility correlated with the return of normal sperm counts and with the quality of seminal fluid in the vas deferens on the testicular side of the obstruction at the time of vasovasostomy. The three most important factors influencing return of fertility after vasovasostomy are (1) a meticulous microscopic technique for reconnection, (2) the duration of time the vas deferens has been obstructed, and (3) the presence or absence of a sperm granuloma at the site of the vasectomy, venting the long-term pressure buildup which otherwise would occur. The presence of a sperm granuloma at the vasectomy site generally ensured the presence of good quality sperm in the vas fluid at the time of vasovasostomy and the recovery of a good sperm count postoperatively. If all three of these factors are favorable, vasectomy should be reversible for most patients.

Bilateral vasectomy has become such a popular method of permanent birth control that a reliable method for ensuring its reversibility is of great importance. Data on more than 300 vasovasostomy patients carefully studied both pre- and postoperatively are providing information that may make it possible for vasectomy to be a reliably reversible method of birth control.

A reasonably accurate microscopic reanastomosis of the vas deferens should be achievable in most patients.[1-5] In unselected patients who remained infertile with poor sperm counts after previous attempts at vasectomy reversal, this study documents that the failure was usually due to a strictured anastomosis, with increased pressure causing oligospermia, low motility, or aspermia. Accurate microscopic reanastomosis was achieved in these otherwise unfavorable surgical candidates, and normal sperm counts were restored in 80% of them.

In addition to the importance of microscopic surgical technique, there are residual effects created by the high pressure subsequent to the vasectomy which can permanently prevent normal fertility even after a successful microscopic reconnection. The data coming out of our prospective studies in this group of patients are revealing approaches to vasectomy and to vasectomy counseling that may eliminate the permanent damage that could occur from this pressure increase. This study presents documentation of the fact that the duration of time since the vasectomy and the presence or absence of a sperm granuloma following the original vasectomy have an enormous influence on success or failure after an anatomically accurate vasovasostomy.

The epididymis can reabsorb fluid and thus withstand some of this increased intravasal pressure after vasectomy. However, the appearance of a sperm granuloma following vasectomy, venting this high pressure, seems to assure the recovery of a normal sperm count after surgically accurate vasovasostomy. In the absence of such a sperm granuloma, the duration of obstruction since the

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vasectomy has a profound effect on the successful return of fertility after vasovasostomy.

METHODS

Patients

The study consists of four groups of patients.

Group 1. The initial group of 42 patients subjected to the microscopic two-layer vasovasostomy technique described in detail by Silber[1-5] have now been followed for 1 to 2 years from the time of surgery. With this first group of patients the technique was being carefully worked out after a large series had been successfully performed in laboratory rats. Seminal fluid was sampled from the testicular side of the obstruction for each patient at the time of the reanastomosis. The age of the patient, the time since the vasectomy, the type of vasectomy performed, and the area in which it was performed were correlated to subsequent sperm count and pregnancy. Sperm counts were measured at monthly intervals after surgery for the first 4 months and then at intervals 4 months apart during the entire follow-up period. No patient was accepted for surgery who did not agree in advance to provide this careful follow-up.

The surgical technique involved a meticulous mucosa-to-mucosa reconnection of the inner canal of the vas deferens along with a separate reapproximation of the muscularis. The anastomosis was carefully inspected with each stitch under $\times 16$ to $\times 25$ magnification to ensure against technical errors. Interrupted sutures of 9-0 nylon were used for each layer, and a GS-16 needle was finally the needle of choice. In the earlier patients, GS-9 and CE-30 needles were used, but these were found to be too large and traumatic. In a few of the early cases, 10-0 nylon was used for the inner mucosal sutures and 6-0 nylon for the outer muscularis. However, it soon became apparent that the 6-0 nylon was too crude and damaging to the muscle layer. The 9-0 nylon was subsequently considered to be ideal both for the inner mucosa and for the outer muscle layer.

In many of these patients a sperm granuloma was seen at the site of the vasectomy, but careful records on the presence or absence of sperm granuloma in these patients were not kept because at that time the significance was not anticipated. Luminal dilatation on the testicular side of the obstruction was noted in all of these patients but was not specifically measured and recorded because its significance was not anticipated.

Group 2. Fifty-three patients had each undergone one to three unsuccessful previous attempts at reversal by other competent urologists. At reoperation, all of these cases involved scarring such that anastomosis to the convoluted portion of the vas or to the tail of the epididymal tubule was required in each of the 53 cases. Of these 53 cases, 23 had been considered surgical "successes" by the original surgeon because of the presence of sperm in the ejaculate postoperatively. All 23, however, had very low counts and poor motility (if any), and none of the wives had become pregnant. Of these 23 patients, 13 had persistent oligospermia with poor motility until the time of reoperation. The other 10 patients, however, had converted from having sperm in the ejaculate to becoming aspermic. This aspermic condition had continued for more than 1 year before they appeared in our clinic for operation. In all of these patients, the former anastomosis was excised and subjected to serial sectioning and, in several cases, longitudinal sectioning. These anastomoses were examined under the operating microscope and histologically on hematoxylin and eosin sections. In each of the 53 cases a microscopic reconstruction was then performed. Seminal fluid was sampled from the testicular side of the obstruction in all cases.

Group 3. One hundred and twenty-one consecutive patients have been operated upon and followed for 6 months with serial sperm count determinations. Recovery of normal sperm count was correlated with the patient's age, the time since the vasectomy, the type of vasectomy originally performed, and the quality of seminal fluid on the testicular side of obstruction at the time of the vasovasostomy. Many of these patients have already impregnated their wives, but the follow-up period is too short to permit an evaluation of the pregnancy rates in this group. It does represent a large number of patients operated upon to determine the factors important in predicting successful recovery of normal sperm counts.

Group 4. Ninety-two consecutive patients have been operated upon more recently and have had a follow-up of 2 to 4 months. These patients represent a prospective study in which careful measurements were made to determine the presence or absence of sperm granuloma at the site of the original vasectomy on either side and the size of the testicular side lumen. On each side the degree of dilatation present at the time of the reconstruction was measured with a micromillimeter rule. This prospective study measuring luminal dilatation and sperm granuloma formation was initiated as it became apparent that these two factors might be extremely important in predicting whether the outcome would be successful.

Grading of Sperm Quality in Seminal Fluid at the Time of Vasovasostomy

In each patient, seminal fluid was sampled from the testicular side lumen with a micropipette and subjected immediately to microscopic observation. Motility was observed on a wet specimen and morphology on a fixed stained specimen. Sperm quality was assessed according to five grades: *grade 1,* many motile, morphologically normal sperm; *grade 2,* many nonmotile, morphologically normal sperm; *grade 3,* mostly sperm heads and degenerated sperm with some morphologically normal sperm, but no motility; *grade 4,* sperm heads only; *grade 5,* no sperm or sperm parts noted.

Almost all specimens could be fitted into one of these five grades. Occasionally, a seminal fluid sample contained many morphologically normal, nonmotile sperm along with a few degenerated sperm and sperm heads. Because the preponderance of sperm in such cases fit into the grade 2 category, the seminal fluid was considered grade 2. Many samples contained sperm heads only, with a very rare morphologically normal sperm. These samples fit into the category of grade 4. No seminal fluid sample was considered to be grade 5 unless absolutely no sperm or sperm parts were noted.

Observations on Vas Deferens Luminal Diameter, Sperm Granuloma, and Type of Vasectomy

At the time of surgery, the fibrotic area of the vasectomy site was excised down to healthy lumen both proximally and distally. The lumen of the vas deferens was measured on both the proximal side and the distal side under the operating microscope with a micromillimeter rule. No artificial dilatation or probing was performed before the measurement of this lumen was made. With a probing instrument or microsound of any kind inserted into the vas deferens, a false impression of luminal diameter can be obtained.

The dimensions of the sperm granuloma were also measured. The diagnosis of sperm granuloma was ascertained by histologic hematoxylin and eosin sections at the site of vasectomy. Several that were thought to be sperm granulomas were suture granulomas, and only those that were proven microscopically to be sperm granulomas were considered in the analysis. However—with only a few exceptions—when a relatively large nodule (greater than 0.25 cm) was noted at the testicular side lumen of the vas deferens, it was generally a sperm granuloma. The distance between the healthy ends of the vas deferens and whether or not the vasectomy was in the convoluted portion were also ascertained.

Evaluation of Previous Attempts at Vasovasostomy

In patients who had undergone a previous attempt at vasovasostomy, the entire anastomotic segment was excised. Under the operating microscope, serial sections were made which demonstrated the area of luminal narrowing and any corresponding sperm granuloma. These segments were kept in order and placed in formalin for serial sectioning and hematoxylin and eosin staining. In several patients we obtained longitudinal sections.

Surgical Considerations in Very Difficult Cases

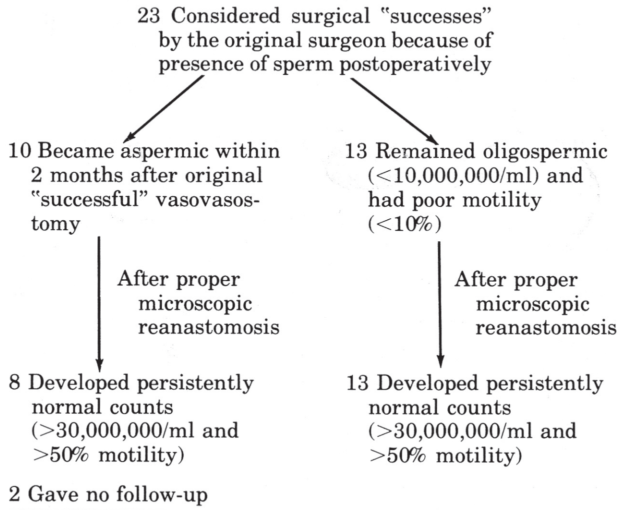
When a very large segment of the vas deferens was missing, the incision often was extended up to the area of the external inguinal ring, or even higher, to free enough healthy vas deferens from surrounding tissue so that the two ends could be brought together without any tension. No matter how large a segment of vas was removed, a good anastomosis could be achieved since we were able to free enough of the healthy vas deferens above and below the area concerned.

In 11 cases, the vasectomy extended down to the tail of the epididymis and in two cases it had removed a portion of the tail of the epididymis going to the mid-epididymal area. In these cases, a good reconnection was achieved by anastomosing the inner lumen of the abdominal end of the vas deferens to the dilated epididymal tubule through which seminal fluid could be seen to be oozing after the scarred tissue was excised. Anastomosis of the inner mucosal lumen of the vas deferens to this epididymal tubule was more difficult than in the routine cases. Thus, we could state that a good reconnection was achievable even in unfavorable cases. With this background, we were interested in determining which factors measured preoperatively would be predictive of success or failure in terms of sperm counts and fertility.

Follow-up Sperm Counts

Sperm counts were arbitrarily considered as normal when they had a concentration of more than 20 million/ml, 50% motility with good progression, and greater than 70% normal forms, according to the criteria of MacLeod and Gold.[6] It is recognized that lower counts can sometimes be found in fertile men and higher counts sometimes in infertile men. It turned out that the semen of most of the patients with "normal" counts actually had in excess of 40 million sperm/ml. All semen samples with good motility had greater than 70% normal forms. In all patients, sperm counts were obtained at monthly intervals postoperatively for up to 4 months and at 2- to 4-month intervals thereafter indefinitely. Only an occasional patient failed to provide follow-up samples.

TABLE 1. *Course of Patients with Previously Unsuccessful Vasovasostomies*



RESULTS

Group 1: Original 42 Patients Followed for 1 to 2 Years. Normal sperm counts usually did not occur in patients until 3 to 8 months following successful surgery. Occasionally a normal sperm count did occur within the first 1 or 2 months, but even in those cases the count tended to rise to higher levels over the succeeding 8 months. In the first 3 months, counts were usually low, most of the sperm were nonmotile, and there were a great many abnormal forms. Eventually these abnormal forms, which represented senescent sperm, were replaced by motile sperm with normal morphology. Pregnancy did not usually occur until after 1 to 6 months following surgery; therefore, any evaluation of pregnancy rates would be premature before at least 1½ years of follow-up.

In the 1½ years, of 42 unselected patients, the wives of 30 have thus far become pregnant, representing a 71% pregnancy success rate. Pregnancy appeared to correlate very well with the sperm count (paticularly the motility score) and also with the quality of sperm seen in the seminal fluid at the time of the original reconstruction. Of the 42 patients, 36 had normal sperm counts, and 28 (78%) impregnated their wives. Two of the six patients with counts below normal achieved pregnancy. Only 7 of these 42 patients had had vasectomies more than 10 years previously.

Group 2: Patients Who Had Had Unsuccessful Previous Attempts at Vasovasostomy. Table 1 summarizes the course of the patients with unsuccessful previous procedures. Histologic examination and serial cross-sectioning of the previous vasovasostomy site demonstrated a severe obstruction in all patients. The 13 patients with oligospermia and poor motility had severe obstruction in every case (see Fig. 1). In most of the cases the obstruction was related to a sperm granuloma with anastomosing channels through which some sperm were traveling. There was no normal lumen in any of these cases. In most of the 10 patients who were aspermic, a sperm granuloma was also present at the site of the obstruction; in others there was merely fibrosis.

Table 2 is a detailed summary of the sperm counts from the 13 patients with oligospermia and infertility after previous attempts at vasovasostomy, and their subsequent sperm counts after microscopic reanastomosis. It would be easy to assume that these patients had a "successful" result from their first operation, but for some unknown reason had poor sperm counts which were very unlikely to lead to pregnancy in the spouse. In each case after microscopic reanastomosis, these patients recovered normal sperm counts.

Table 3 summarizes the sperm counts in 10 patients considered surgical "successes" with conventional techniques who had become aspermic within 4 months after the original vasovasostomy. In these patients also, obstruction was noted at the site of the previous attempt at vasovasostomy.

Of the 53 patients reoperated upon after previous failure of vasovasostomy, all were noted to have obstruction. Of the 51 patients who could be followed, 41 developed normal sperm counts after reanastomosis. Thirty-nine had grade 1, 2, or 3 sperm in the vas fluid on the testicular side of obstruction at the time of microscopic reanastomosis. Thirty-eight of those thirty-nine developed

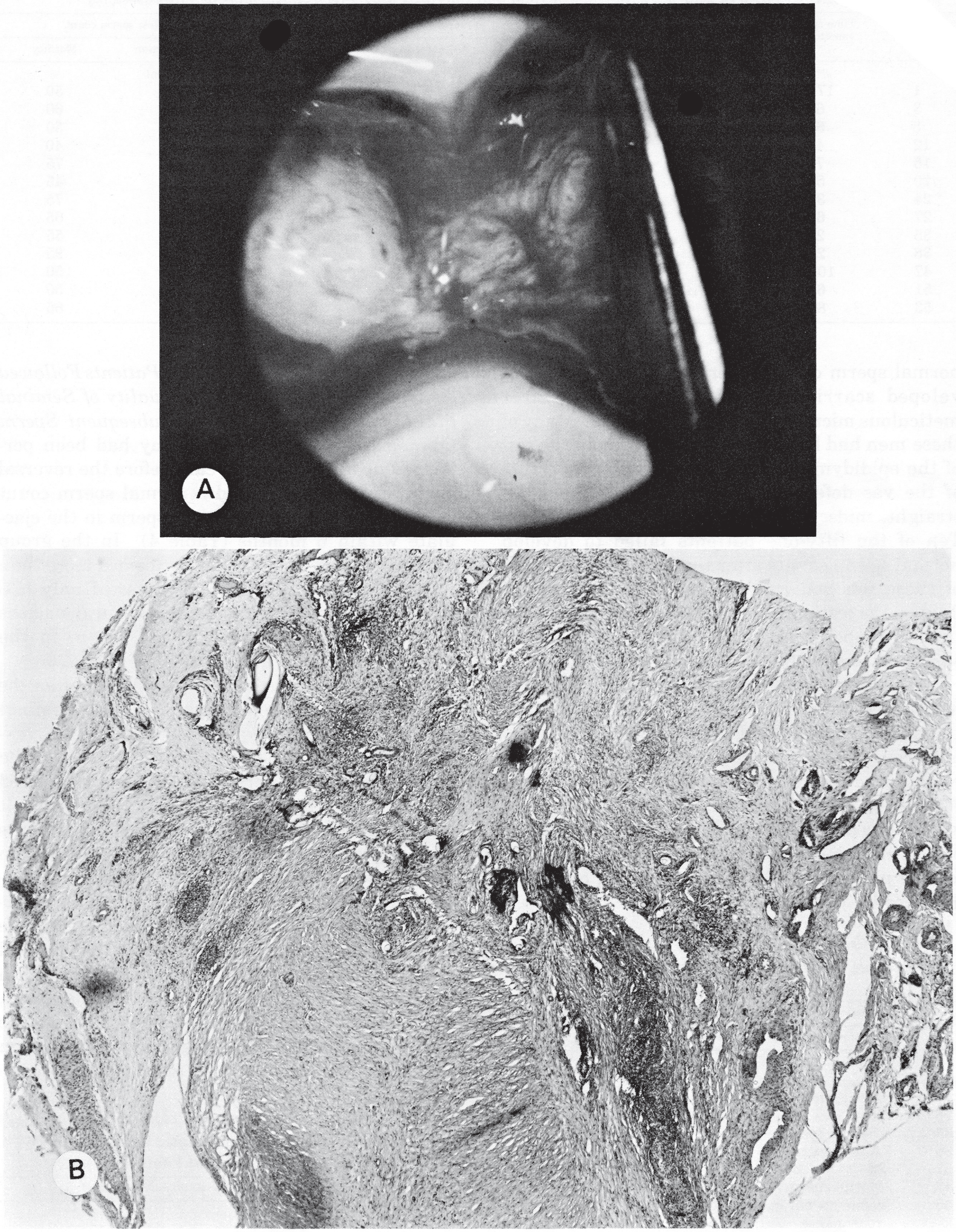


FIG. 1. *A*, View through the operating microscope of obstructed conventional vasovasostomy in a patient with oligospermia, poor motility, and infertility. *B*, A histologic section through this conventional anastomosis in the same patient. Note the many sutures and the lack of a normal lumen.

TABLE 2. *Thirteen Patients with Oligospermia and Infertility after Previous Attempts at Vasovasostomy*

Patient	Time since vasectomy	Time since unsuccessful reversal attempt	Sperm count prior to reoperation		Time since reoperation	New sperm count	
			Concentration	Motility		Concentration	Motility
	yr	*yr*	*million/ml*	*%*	*mo*	*million/ml*	*%*
1	17	4	4	5	12	53	50
3	6	7/12	Occasional sperm	0	12	86	60
8	6	8/12	7	5	2	42	50
12	4	3	5	1	5	55	40
16	7	1	3	20	3	30	75
20	5	2	6	10	4	72	45
24	3	2	8	0	6	20	75
27	6	5	Occasional sperm	0	8	39	65
35	2	1	Occasional sperm	0	5	32	55
38	2	1	3	0	8	80	95
47	10	6	2	0	4	61	50
51	6	1 6/12	Occasional sperm	0	1	20	50
53	8	1	3	20	1	18	65

normal sperm counts after reoperation. One developed scarring and obstruction even after meticulous microsurgical reanastomosis. Many of these men had had vasectomies involving the tail of the epididymis or the deep convoluted portion of the vas deferens. None involved simply the straight, midscrotal portion of the vas deferens. Ten of the fifty-one patients failed to develop normal sperm counts after this reoperation. Nine of these ten had had no sperm in the seminal fluid on the testicular side of the obstruction at the time of reoperation. Thus, only one case of reoperation clearly failed because of obstruction.

These 51 patients could be classified into those whose vasectomies had been performed less than 10 years previously and those whose vasectomies had been performed more than 10 years previously. Ninety-one per cent developed normal sperm counts after reoperation when the original vasectomy had been performed within 10 years, but when the original vasectomy had been performed more than 10 years previously, only 59% developed a normal count.

TABLE 3. *Ten Surgical "Successes" with Conventional Technique Who Became Aspermic within 2 Months after Original Vasovasostomy*

Patient	Original sperm count		Subsequent sperm count	Sperm count after reoperation	
	Concentration	Motility		Concentration	Motility
	million/ml	*%*		*million/ml*	*%*
2	19	2	0	86	60
5	"Many motile"		0	50	70
28	20	50	0	85	80
33	"Sperm seen"		0	22	50
36	"A few sperm"		0	18	45
37	28	60	0	133	98
43	"Motile sperm"		0	Not yet reported	
45	"Motile sperm in reasonable numbers"		0	89	30
50	90	60	0	20	50
52	"Some sperm"		0	Not yet reported	

Group Three: 121 Consecutive Patients Followed for Up to 8 Months, Relating Quality of Seminal Fluid at Time of Surgery to Subsequent Sperm Counts. If a patient's vasectomy had been performed no more than 10 years before the reversal operation, 91% developed a normal sperm count within 6 months and 94% had sperm in the ejaculate within 6 months (Table 4). In the group whose vasectomies had been performed more than 10 years prior to the vasectomy reversal, only 35% obtained normal sperm counts within 6 months following surgery, and 47% had sperm in the ejaculate 6 months after surgery.

Table 5 compares the duration of time since the original vasectomy and the quality of the seminal fluid at the time of vasovasostomy. If the vasectomy had been performed within 5 years of the reversal operation, normal sperm counts occurred in every patient postoperatively. However, it is interesting to note that only 2 of 56 patients in this group had no sperm in the vas fluid on either side at the time of reconstruction. In looking at the group whose vasectomies had been performed between 6 and 10 years earlier, we see that most patients did have sperm in the vas fluid at the time of surgery, but there were more with no sperm at the time of surgery. In this group, when there was sperm in the vas fluid at the time of surgery, 25 of 27 developed normal sperm counts. When there was no sperm at all in the

TABLE 4. *121 Consecutive Patients Followed for 6 Months: Relationship of Sperm Counts after Vasovasostomy to Time since Original Vasectomy*

Sperm count	Years since original vasectomy	
	<10	>10
Normal	86 (91%)	9 (35%)
Low	3 (3%)	3 (12%)
No sperm	6 (6%)	14 (53%)

TABLE 5. *121 Consecutive Patients Followed for 6 Months: Relationship of Sperm Counts after Vasovasostomy to Time since Original Vasectomy and Seminal Fluid Quality at Time of Vasovasostomy*

Sperm count	Years since original vasectomy					
	0–5		6–10		>10	
	Sperm in vas fluid	No sperm in vas fluid	Sperm in vas fluid	No sperm in vas fluid	Sperm in vas fluid	No sperm in vas fluid
Normal	54	2	25	5	9	0
Low	0	0	2	1	3	0
No sperm	0	0	0	6	0	14

vas fluid in this group of patients, only 5 of 12 developed normal sperm counts, 6 had sperm in the ejaculate, and 6 had no sperm at all in the ejaculate as long as 6 months postoperatively.

In the group whose vasectomies had been performed more than 10 years earlier, we find that only 12 of 26 had any sperm in the vas fluid at the time of surgery. Furthermore, those who did not have sperm in the vas fluid at the time of surgery, and whose vasectomies had been performed more than 10 years earlier, did not show sperm in the ejaculate up to 6 months postoperatively. Among those who did have sperm in the vas fluid whose vasectomies had been performed more than 10 years previously, 9 of 12 (75%) developed normal sperm counts. As long as there were sperm in the vas fluid at the time of surgery, the patient had sperm in the ejaculate postoperatively. In addition, the odds were favorable for having a normal count, although the odds were better if the vasectomy had been performed more recently.

These findings demonstrate clearly the deleterious effect of a prolonged duration of obstruction on successful return of fertility after reconstruction of the vas deferens. A large percentage of patients whose vasectomies had been performed more than 10 years earlier had no sperm in the seminal fluid at the time of vasovasostomy. Those patients with no sperm in the seminal fluid at the time of vasovasostomy were much less likely to develop a normal sperm count if vasectomy had been performed more than 10 years earlier.

A close look at these figures suggests that nearly every anastomosis in this large series was patent, since the only cases in which no sperm appeared postoperatively were those in which there were no sperm on the testicular side of the obstruction preoperatively. As long as there were sperm in the vas fluid preoperatively, there were sperm in the ejaculate postoperatively and a 95% chance of having a normal sperm count after surgery. If there were normal sperm in the vas fluid at the time of vasovasostomy and vasectomy had been performed within 10 years of the vasovasostomy, there was a 98% chance that the patient would develop a normal sperm count within 6 months following the vasovasostomy.

Group Four: Prospective Study on Sperm Granuloma and Vas Dilatation. The most significant findings in this series were in these 92 consecutive patients whose ages ranged from 21 to 55 years. The time since the vasectomy and repair varied between 1 month and 28 years. All patients were azoospermic at the time of the vasovasostomy. This is the most recent series of patients and the group in which we have the most complete records on sperm granuloma, vas lumen diameter, and the quality of sperm in the vas fluid in relation to subsequent sperm counts. Tables 6 and 7 summarize the findings in the vas fluid at various intervals after vasectomy in relation to the presence or absence of a sperm granuloma in 184 vasa deferentia in these 92 consecutive patients. Of the 184 vasa, a sperm granuloma was noted in 59 (32%) at the site of the vasectomy.

In the group with sperm granuloma (Table 6), a total of 92% had many morphologically normal motile or nonmotile sperm in the vas fluid. No vas in the group with sperm granuloma failed to have some good quality sperm in the seminal fluid. None of the patients with sperm granuloma, even when the vasectomy had been performed more

TABLE 6. *Contents of Seminal Fluid at Various Intervals after Vasectomy in Relation to Presence or Absence of Sperm Granuloma: Patients with Sperm Granuloma*

Seminal fluid	Years since original vasectomy			All patients regardless of time since vasectomy
	0–5	6–10	>10	
Grade 1: many motile normal sperm	12 (63%)	15 (68%)	11 (61%)	38 (64%)
Grade 2: many nonmotile normal sperm	7 (37%)	5 (23%)	4 (22%)	16 (28%)
Grade 3: sperm heads with some normal sperm	0 (0%)	2 (9%)	3 (17%)	5 (8%)
Grade 4: sperm heads only	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Grade 5: no sperm	0 (0%)	0 (0%)	0 (0%)	0 (0%)

TABLE 7. *Quality of Sperm in Seminal Fluid at Various Intervals after Vasectomy in Relation to Presence or Absence of Sperm Granuloma: Patients with No Sperm Granuloma*

Sperm quality	Years since original vasectomy			All patients regardless of time since vasectomy
	0–5	6–10	>10	
Grade 1: many motile normal sperm	8 (12%)	0 (0%)	0 (0%)	8 (6%)
Grade 2: many nonmotile normal sperm	2 (3%)	0 (0%)	0 (0%)	2 (1%)
Grade 3: sperm heads with some normal sperm	18 (26%)	5 (17%)	4 (14%)	27 (22%)
Grade 4: sperm heads only	26 (38%)	18 (62%)	12 (43%)	56 (45%)
Grade 5: no sperm	14 (21%)	6 (21%)	12 (43%)	32 (26%)

than 10 years earlier, failed to have sperm in the ejaculate and none of them had sperm quality as poor as grade 4. From Table 6 it is apparent that no matter how long ago the vasectomy had been performed, the presence of a sperm granuloma resulted in a very high quality of sperm in the vas fluid.

A look at the vasa that had no sperm granuloma associated with them (Table 7) reveals a startlingly different picture. The absence of the sperm granuloma thus had a dramatically deleterious effect on the quality of sperm seen in the vas fluid at the time of vasovasostomy. By evaluating this finding according to the number of years since the vasectomy, it was apparent that in the absence of the sperm granuloma, the duration of obstruction had a very pronounced effect on the findings in the seminal fluid. Thus it was apparent that in the presence of a sperm granuloma there was a very small deleterious effect due to increasing duration of time since vasectomy; but when there was no sperm granuloma, there was a very important deleterious effect created by an increasing duration of the time since vasectomy. The presence of the sperm granuloma ensured a high quality of sperm in the vas fluid.

Table 8 summarizes the data regarding the inner diameter of the vas deferens lumen on the testicular side of the obstruction in relation to the presence of a sperm granuloma. When there was a sperm granuloma, 97% of vasa had a lumen diameter of 0.75 mm or less, and 83% had a lumen diameter of 0.50 mm or less. None had a luminal diameter greater than 1 mm when there was a sperm granuloma. Thus, in the presence of a sperm granuloma, the mean inner diameter (± standard deviation) on the testicular side of the obstruction was 0.52 ± 0.15 mm. The inner diameter of the vas lumen on the abdominal side of the obstruction had less variation and was 0.32 ± 0.08 mm.

Table 9 demonstrates that in the absence of a sperm granuloma there was much greater dilatation of the testicular side lumen. In this case the mean inner diameter was 1.05 mm ± 0.24. Only 4% of these vasa had a lumen diameter of 0.5 mm or less. Forty-one per cent had a lumen diameter greater than 1.0 mm. Thus, a dramatic increase in the amount of dilatation of the lumen on the testicular side of the obstruction was associated with the absence of a sperm granuloma.

Table 10 summarizes the quality of sperm in the seminal fluid in association with varying degrees of dilatation of the vas lumen on the testicular side. Grade 1 or grade 2 sperm in seminal fluid was associated with less dilatation of the testicular side lumen than was grade 3, grade 4, or grade 5 sperm in the vas fluid ($P < 0.001$).

In Table 11, it can be seen that only 34% of the vasa were obstructed in the midscrotal, straight portion. Sixty-six per cent of the cases involved the convoluted portion of the vas deferens or the tail of the epididymis. These represent a group of patients that usually would not be considered candidates for a vasovasostomy. Thus, these cases seem to have been selected toward the most difficult rather than toward the more favorable ones.

In 19 patients in this prospective group a sperm granuloma was noted on only one side. This group offered an opportunity to determine whether there was any systemic effect of a sperm granuloma on one side that would affect the quality of sperm in the vas fluid on the other side. On the side with sperm granuloma, there were always many morphologically normal motile sperm or many morphologically normal nonmotile sperm (grade 1

TABLE 8. *Inner Diameter of Vas Deferens Lumen on Testicular Side of Obstruction in Relation to Presence or Absence of Sperm Granuloma*

Vas inner diameter[a]	Sperm granuloma
mm	
0.33	8 (20%)
0.50	25 (63%)
0.75	6 (15%)
1.00	1 (3%)
1.25	0 (0%)
1.50	0 (0%)

[a] Mean inner diameter ± standard deviation = 0.52 ± 0.15 mm. The inner diameter of the vas lumen on the abdominal side of the obstruction = 0.32 ± 0.07 mm.

TABLE 9. *Inner Diameter of Vas Deferens Lumen on Testicular Side of Obstruction in Relation to Presence or Absence of Sperm Granuloma*

Vas inner diameter[a]	No sperm granuloma
mm	
0.33	0 (0%)
0.50	3 (4%)
0.75	14 (18%)
1.00	28 (36%)
1.25	25 (32%)
1.50	7 (9%)

[a]Mean inner diameter ± standard deviation = 1.05 ± 0.24 mm. The inner diameter of the vas lumen on the abdominal side of the obstruction = 0.32 ± 0.07 mm.

or grade 2). On this side sperm poorer than grade 2 were never found. However, on the side without a sperm granuloma, 7 of the 19 patients had no sperm whatsoever. In 10 of the 19, sperm heads only were found (grade 4), and only 2 of the 19 had grade 2 sperm. No vasa on the side without a sperm granuloma contained grade 1 sperm. Thus, a very dramatic benefit is conferred to the testis and the vas fluid on the side with the sperm granuloma that does not extend to the side without the sperm granuloma.

The early (3-month) follow-up results of sperm counts on 61 of the 92 patients in this prospective series can be summarized. Results in the other 31 patients in this series are too early to evaluate. These 61 patients represent the first consecutive patients within this series of 92. In 28 patients who had a sperm granuloma on either one or both sides, whether the vasectomy had been performed less than 10 years or more than 10 years earlier, normal sperm counts were found within 3 months of the surgery. In 33 patients who had no sperm granuloma on either side, the duration of time since vasectomy had a very important influence on the result. When the vasectomy had been performed less than 10 years previously in patients with no sperm granuloma, 88% still developed normal sperm counts. However, when vasectomy had been performed more than 10 years earlier, only 29% had normal sperm counts.

DISCUSSION

There will always be a very small percentage of patients who wish to have their vasectomies reversed and to father children again. Vasectomy will be a much more acceptable method of birth control if its reversibility can be made more likely.

The microscopic technique for vasovasostomy which we have described can generally obtain an accurate anastomosis of the disconnected vas. In the occasional case in which obstruction occurs postoperatively, a reoperation can usually provide an accurate reconnection the second time, with a very low risk of obstruction.

TABLE 10. *Quality of Sperm in Seminal Fluid with Varying Degrees of Dilatation of Vas*

Sperm quality	Vas inner diameter (mean ± SD)
	mm
Grade 1: many motile normal sperm	0.59 ± 0.29[a]
Grade 2: many nonmotile normal sperm	0.69 ± 0.31[b]
Grade 3: sperm heads with normal sperm	1.06 ± 0.26[b]
Grade 4: sperm heads only	1.08 ± 0.25
Grade 5: no sperm	1.04 ± 0.25
Inner diameter on nonobstructed side	0.32 ± 0.07[a]

[a]$P < 0.01$.
[b]$P < 0.0001$.

It is clear from the patients followed here that the quality of sperm in the vas fluid at the time of vasovasostomy has a strong bearing on the likelihood of success. Those with few or no sperm at all in the seminal fluid at the time of surgery had a poorer chance of developing normal sperm counts within the 1st year following surgery, despite an accurate reconnection. The presence of normal sperm in the vas fluid at the time of reconstruction gives over a 95% chance of a subsequent normal sperm count.

In most of the series reported on vasovasostomy, accurate sperm counts are not given and the only thing reported is the presence or absence of sperm in the ejaculate.

It is startling how frequently sperm appear in the ejaculate after a vasovasostomy no matter how crude the technique. The mechanism is that sperm leak out of the testicular side and form a sperm granuloma which becomes a bridge with anastomosing channels and canaliculi to the other side. There is no true anastomosis in such cases, but some sperm are able to traverse through these multiple little canaliculi and crevices in the sperm granuloma, and reach the other side. Usually the sperm counts are low in these cases and motility is very poor. Even when the sperm count initially is reasonable, it usually drops to much lower levels with time as the vas fibroses. At least one-half of these so-called successful cases usually become

TABLE 11. *Site of Vasectomy and Amount of Vas Removed in 188 Consecutive Patients*

Type of vasectomy	%
Midscrotal, straight portion involved	34
Convoluted portion with small segment excised	21
Over 2.4 cm excised *and* convoluted portion excised	45

aspermic eventually and many of them remain oligospermic.

In order to obtain a high incidence of normal sperm counts and a high rate of pregnancy, an accurate microscopic channel must be reconstituted with meticulous surgical technique. Furthermore, only by studying these patients both pre- and postoperatively may factors influencing recovery of fertility other than surgical technique be ascertained. It is apparent that some patients who are fertile prior to vasectomy do not recover their normal fertility or impregnate their wives despite an accurate microscopic reconnection. It was the purpose of this clinical study to determine other factors that might be deleterious to the redevelopment of fertility.

We now have documentation that the duration of obstruction is one very important factor influencing the return of normal sperm counts and fertility after operation. In general, those patients whose vasectomies were performed within 10 years of reversal can expect at least a 90% chance of recovering normal sperm counts after a proper microscopic operation. However, only about 50% of those whose vasectomies were performed more than 10 years previously can expect the return of a normal sperm count despite a good anastomosis. It does seem apparent that once a normal sperm count is obtained, the incidence of pregnancy is only slightly less than that in patients who have not had a vasectomy.

Perhaps a more important factor influencing the success or failure of the return of fertility after vasovasostomy is a sperm granuloma associated with the original vasectomy. If the vasectomy allowed a sperm granuloma to form on either side, it appears that the patient has better assurance that he will recover a normal sperm count if the vasovasostomy stays open. The presence of a sperm granuloma may represent a safety-valve mechanism to allow venting of a high pressure on the testicular side of the vas deferens. The presence of this sperm granuloma represents persistent leakage of sperm at the vasectomy site and modifies the deleterious effect of high intravasal and epididymal pressure after vasectomy.

In patients who have unilateral sperm granulomas, the protection conferred by the sperm granuloma is only on the side of the granuloma. Thus it does not appear that the sperm granuloma has any systemic benefit which would affect both testes. These data appear to be strong arguments for the postulate that a failure of recovery of fertility after anatomical reconnection of the vas deferens is due to the local effects of high pressure created by the vasectomy. This intravasal pressure appears to be lower in patients who have sperm granulomas.

The concept of a partial obstruction or a poor connection resulting in oligospermia, poor motility, and infertility after vasovasostomy has been challenged by Schmidt[7] in a recent postgraduate course. Yet the data from three separate animal studies on the effect of installing intavasal devices with lumina of various sizes have demonstrated that narrowing of the vas lumen decreases the sperm count and the quality of the sperm.[8-10] Also, the fact that failure of vasovasostomy performed with conventional techniques did not prevent success with subsequent microsurgical vasovasostomy adds strong support to the contention that many vasovasostomy failures are direct results of inadequate sperm passage. Successful pregnancy was very closely correlated with sperm count and sperm quality in this study as well as in the report on vasovasostomy by Phadke and Phadke.[11] Steinberger and Lipschultz[12] and Schoysman[13] have also recently stated that oligospermia can be caused by stictures of the epididymal tubule. Finally, Freund and Davis[14] have shown that most of the sperm in the ejaculate travel from the epididymis at the time of intercourse, and it is logical that a poor anastomosis would have a deleterious effect.

There are many studies in animals to support the data now reported here on sperm granuloma after vasectomy in humans. In 1924 Van Wagenen[15,16] showed that ligation of the efferent ductules of rats was followed immediately by an increase in diameter of the seminiferous tubules and rigidity of the entire testis. After vasoligation, there was a delayed development of intratubular pressure. Van Wagenen attributed this delay to the venting of pressure by dilatation of the vas and the formation of a spontaneous sperm granuloma at the site of the ligation. Later, Neaves[17] and Smith[18] demonstrated complete destruction and atrophy of the seminiferous tubules after efferent ductule ligation. There was no damage to the rat testes after vasectomy because of the spontaneous formation of sperm granuloma as well as absorptive properties of the epididymis, preventing serious increase in intratubular pressure following vas ligation.

In our earlier series, it became readily apparent that patients who are vasectomized undergo dilatation of the vas deferens and epididymal tubule, but some appear to undergo more dilatation while some have less impairment of sperm appearance in the vas fluid. This study appears to confirm in humans that vasectomy results in a buildup of pressure in the vas deferens on the testicular side of the obstruction. This pressure goes back to the epididymis and may result in an inhibition of sperm output in the vas fluid. Any approach which would keep the pressure reduced within that system might allow greater assurance of recovering fertility.

There are reabsorptive processes in the epididymal system which vent pressure sufficiently to confer considerable protection. Turner et al.[19] sampled fluid by micropuncture from four areas of the rat epididymis from the caput to the distal cauda and documented a large water reabsorption from the epididymal lumen as the seminal fluid traveled toward the vas from the testes. They noted an increase in sperm concentration from the testes toward the tail of the epididymis. They postulated an active sodium pump driving this concentration gradient. It would appear that this absorptive capacity of the epididymis probably affords considerable protection to the testes after vasectomy. Data in the ram also support this postulate.[20]

To give the patient the maximal assurance of a low-pressure system and return of normal sperm output after vasectomy reversal, the formation of a sperm granuloma should perhaps be encouraged rather than avoided. This would allow venting of pressure to assure the patient the restoration of his fertility if an accurate vasovasostomy can be achieved. Since 32% of the vasa we examined demonstrated sperm granuloma, and since these patients did not have any particular complaints or problems referable to their sperm granuloma, it would appear that this is not really a serious complication of vasectomy, so long as recanalization has not occurred. One may be able to prevent the likelihood of recanalization in this type of situation by carefully cauterizing the abdominal side of the vas deferens at the time of vasectomy[21] but doing nothing to the testicular side.

Alexander[22] has achieved excellent results in monkeys by using nonmicroscopic techniques. However, most of her animals developed sperm granulomas after vasectomy (assuring low pressure), and all underwent vasovasostomy within 6 months after vasectomy. With this kind of situation, almost all animals should recover fertility. It may be that some of her oligospermic monkeys which were subfertile would have done even better with a microscopic operating technique. In the clinical situation where the vasectomy was performed long ago and there is usually no sperm granuloma to vent the high pressure, the prognosis is not as good, and a meticulous anastomosis may be more important.

It is clear from our study that postvasectomy intravasal pressure (duration and degree) have a strong influence on the outcome of eventual vasovasostomy.[23] If vasectomy is performed by cauterizing the abdominal side vas lumen, and doing nothing to the testicular side, a sperm granuloma is more likely to form, less pressure will develop, and subsequent reversibility is more probable.

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