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Considerations in Selecting a Postvasectomy Semen Examination Regimen

S. D. MUMFORD, J. E. DAVIS, M. FREUND

International Fertility Research Program, Research Triangle Park, North Carolina, New York, New York; New Jersey College of Medicine and Dentistry, Camden, New Jersey, USA

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The criteria for declaring a vasectomized man sterile have been the subject of debate for many years, yet most suggested regimens differ. The problem lies in the remaining unanswered physiologic questions of such a fundamental nature as to frustrate attempts to formulate a regimen based strictly on medical considerations. The rates of disappearance of sperm following vasectomy vary considerably among men. The physiologic basis for these variations are herein discussed for the first time. At present, regimens reflect, for the most part, social considerations, according to the values and perceptions of the individual physician. The problems raised by postvasectomy residual sperm and current formulation of regimens are described.

Introduction

The minimum criteria for declaring that a vasectomized man is sterile have been debated for many years. More recently, there has been a call to establish a uniform standard for the determination of sterility after vasectomy [1]. There are many reports on "definitive" studies conducted to determine the best postvasectomy semen examination regimen. Yet most suggested regimens differ from one another. A review of the literature concerning (1) the problems raised by stored sperm postvasectomy, (2) the wide variation relative to stored sperm found among men and (3) germane and rather basic unanswered questions of physiology suggests that these criteria are not based on medical judgment alone, but, at least in part, on nonmedical considerations. This paper explores the manner in which postvasectomy semen examination regimens are currently formulated and presents the reasons why it would be difficult to defend the selection of any particular uniform standard.

Postvasectomy residual sperm

The literature on postvasectomy residual sperm generally underplays the enormous variations found among individual men with respect to numbers, rate of elimination and location of stored sperm. The discussions here will be concerned with the average man, but emphasis will be placed on this variability.

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In attempting to identify criteria regarding postvasectomy semen, a clear perception of the mechanism of ejaculation in man is critical. Yet, despite its obvious biologic importance, this mechanism has not been completely described because it is not fully understood [2]. Mitsuya and his associates [3] approached the problem by using X-ray cinematography to observe ejaculation by 16 men. Their study was not intended to be definitive, and uncertainties remained, even with respect to the more obvious events that occurred. Nevertheless, their description is useful for our purposes.

Just prior to ejaculation, sperm are rapidly transported from the epididymis to the ampulla (Fig. 1). Mitsuya noted that during the sexual excitement stage, "the many diverticles and ramifications, tortuous and winding forms of the vas

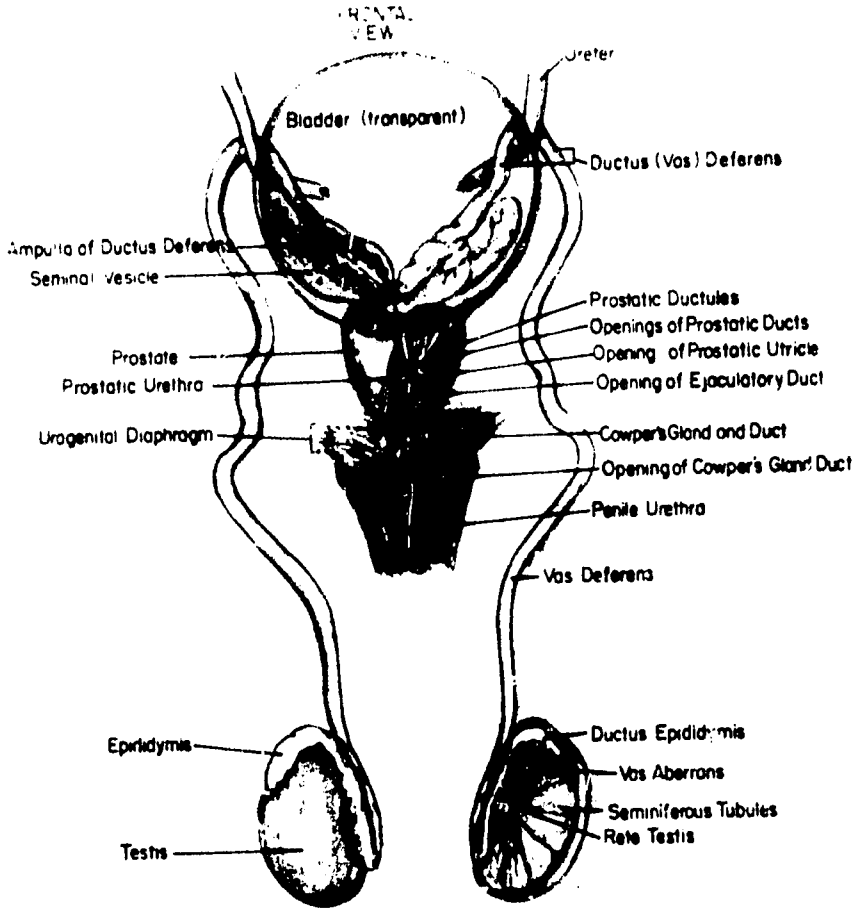


Fig. 1 The accessory organs of reproduction

were changed into a linear type and the vas was pulled toward the seminal vesicle so that the sharp angle formed by the ampulla and vesicle disappeared". In the preejaculatory stage, the seminal vesicle becomes strikingly tense and its peristaltic movement begins. The contents of the ampulla are discharged into the prostatic urethra, apparently directly through the ejaculatory duct without first entering the seminal vesicle. Approximately one tenth of the contents of the seminal vesicle are then propelled into the prostatic urethra, where pressure continues to build as prostatic secretions are added. The pressure reaches a point where a large fraction of these contents are propelled through the penile urethra and the first discharge occurs. The seminal vesicle, without involvement of the ampulla, then makes a second up and down peristaltic movement, activating the process in the same manner and measure as before, to produce the second discharge. The events leading to the second discharge are further repeated, on the average, six times during one ejaculation.

Neither the ejaculatory duct nor the prostatic urethra is completely emptied during ejaculation. The contents of the ejaculatory duct were observed being regurgitated into the ampulla during the immediate postejaculatory period and, in one of the 16 subjects, into the seminal vesicle.

This method does not permit determination of whether all sperm are propelled from the vas and its ampulla during ejaculation, but it does appear that at least the bulk of these fluids are propelled from these two structures during ejaculation. Neither could it be determined whether the regurgitated fluid contained any sperm. And, if any are present, what fraction of the sperm seen after vasectomy do they account for?

Potential storage sites for sperm

The seminal vesicle is a hostile environment for sperm and it is unlikely that live sperm could survive there [4]. Mitsuya and his colleagues discovered that the contents of the ejaculatory duct in one of the 16 subjects studied were regurgitated into the seminal vesicle, which is not completely emptied during an ejaculation. This phenomenon may account for the rare patient who has an occasional dead sperm in his semen up to 15 months postvasectomy.

The nonampullary portion of the vas deferens is not a significant storage site because only 2% of the sperm are stored there [5]. However, the considerable variation among individual men, with respect to the proportion of sperm contributed by the ampulla at the time of ejaculation, suggests a differentiation in the proportion of sperm stored in the vas deferens.

After vasectomy, the ampulla of the vas serves as the principal storage site for sperm, which are either transported there between ejaculatory periods by the spontaneous motility of the vas or are a residue from previous ejaculations [6]. The mucosal lining of the cavernous ampulla is marked by numerous convolutions

Table 1

Sperm concentration (10^6/specimen) before

No.	Preoperative semen specimen	Postoperative semen 1	2	3	4
1	92.800	4.200	0.400	0.050	0.085
2	15.780	22.540	0.225	0.020	0.020
3	25.270	0.090	0.006	0.008	0
4	263.190	42.840	0.560	0.035	0.085
5	191.800	0.210	0.038	0.007	0
6	232.000	298.620	145.600	38.080	11.160
7	90.100	18.240	1.950	11.440	0.070
8	114.120	32.890	5.500	4.020	0.250
9	21.465	7.875	0.725	0.180	0.175
10	403.190	2.560	0.235	0.006	0.004
11	35.267	10.010	1.280	0.640	0.560
12	145.130	15.180	1.040	0.980	0.960
13	455.180	59.850	44.380	8.100	0.900
Mean conc.	160.407	39.623	15.534	4.890	1.098

Source: See Ref. [7].

and crevices. The ampulla's structure may vary considerably among men, yet, this is seldom mentioned, reflecting an inadequate appreciation of its considerable implications in the elimination of stored sperm after vasectomy.

Wide individual variations in the number of stored sperm

Until now, Freund and Davis [7] have published the most informative data on the disappearance rate of spermatozoa from the ejaculate following vasectomy. This work is particularly revealing as it presents raw data that reflect enormous variation among men (Table 1). In this small series of 13, the patient with the most sperm after vasectomy was found to have retained 4745 times as many sperm as the patient with the least (Table 2). The differences among the others were also wide.

Table 3 shows that a single prevasectomy sperm count is an inadequate indicator of the number remaining after vasectomy. One patient had 1638 times as many sperm remaining relative to this prevasectomy count than another and the variation among the rest was again quite wide.

Table 4 shows that, as expected from this description of the mechanism of ejaculation, volume of seminal fluid is not related to the number of stored sperm, the total preoperative sperm count or to the number of ejaculations required before azoospermia is reached. The wide variation among men, with respect to

and after vasectomy (N = 13)

specimens						Total of first ten
5	6	7	8	9	10	
0.135	0.021	0.012	0	0	0	4.902
0.020	0	0	0	0	0	22.825
0	0	0	0	0	0	0
0.004	0.008	0	0	0	0	43.532
0	0	0	0	0	0	0.255
0.017	0.011	0.015	0	0	0	493.503
0.110	0.105	0.050	0.225	0.300	0.028	32 518
0.225	0	0.075	0.050	0.050	0.045	43.105
0	0.014	0	0	0	0	8.969
0.150	0.120	0.035	0.001	0	0	3.111
0.040	0.050	0.060	0.052	0.040	0.045	12.777
1.360	0.115	0.100	0	0	0.300	20.035
1.400	1.100	0.700	0.575	0.060	0.110	117.175
0.266	0.119	0.081	0.069	0.035	0.041	61.754

Table 2

Comparison of patients with respect to number of stored sperm remaining postvasectomy (using the patient with the least number of sperm remaining as a base) (N = 13)[a]

Patient No.	Number of sperm remaining postvasectomy (in millions)	Multiple[b] as compared to patient with least number of sperm remaining[c]
3	0.104	1
5	0.255	2
10	3.111	30
1	4.903	47
9	8.969	86
11	12.777	123
12	20.035	193
2	22.825	219
7	32.518	313
8	43.105	414
4	43.532	419
13	117.175	1127
6	493.503	4745

[a] Total number of sperm remaining equals sperm contained in first ten ejaculates. For purposes of this analysis, sperm contained in additional ejaculates would be insignificant.

[b] Multiple obtained by dividing number of patient's remaining sperm by the number of remaining sperm in the patient with the least number (0.104).

[c] In other words, patient 10 had 30 times as many sperm remaining as patient 3, and patient 6 had 4745 times as many remaining as patient 3.

Source: Derived from data presented in Ref. [7].

Table 3

Comparison of patients by the number of preoperative sperm and of remaining stored sperm after vasectomy (N = 13)[a]

Patient No.	Preoperative total sperm count (single specimen)	Number of sperm remaining postvasectomy (in millions)	Total sperm remaining as compared to the preoperative total count (in %)	Multiple[b] as compared to patient with least number of sperm remaining relative to preoperative total count[c]
5	191.800	0.255	0.13	(1)
3	25.270	0.104	0.41	3
10	403.190	3.111	0.77	6
1	92.800	4.903	5.30	40
12	145.130	20.035	13.00	100
4	263.190	43.532	17.00	131
13	455.180	117.175	26.00	200
7	90.100	32.518	36.00	277
11	35.267	12.777	36.00	277
8	114.120	43.105	38.00	292
9	21.465	8.969	42.00	323
2	15.780	22.825	144.00	1108
6	232.000	493.503	213.00	1638

[a] Total number of sperm remaining equals sperm contained in first ten ejaculations. For purposes of this analysis, sperm contained in additional ejaculates would be insignificant.

[b] Multiple obtained by dividing the percent of sperm remaining compared to the preoperative total count by this same percentage for the patient with the least number of sperm relative to the preoperative total count (0.13%).

[c] In other words, patient 10 had six times as many sperm remaining relative to his preoperative total count as did patient 5, and patient 6 had 1638 times as many sperm remaining relative to his preoperative total count as did patient 5.

Source: Derived from data presented in Ref. [7].

average volume of seminal fluid emitted with each ejaculation, can be seen in Table 4, the lowest and highest volumes differing by a factor of 10. The number of ejaculations required to reach azoospermia varies as well. One patient reached azoospermia by his fourth ejaculate while four of the 13 had not reached azoospermia by their tenth ejaculate. These data also show that the number of ejaculations required to reach azoospermia is not related to prevasectomy sperm count or to the number of sperm remaining in the tract after vasectomy.

Admittedly, Freund and Davis's group was quite small. However, Lee [8] replicated their study with 50 patients and had similar results (Table 5). Furthermore, with another group of 50 patients, where no preoperative specimen was obtained, Lee found postoperative results essentially the same. More recently, Jouannet and David [9] reported similar findings in an extensive study of 76 men.

These results suggest that the wide variations in the rate of elimination of sperm after vasectomy among individual men are due to distinctive constructions

Table 4

Relationship of volume of seminal fluid, number of stored sperm, total preoperative sperm count and number of ejaculations required to reach azoospermia

Patient No.	Total preoperative sperm count (millions)	Sperm remaining postvasectomy (millions)	Total volume of seminal fluid emitted in first ten ejaculates (ml)	First azoospermic postvasectomy ejaculate
2	15.780	22.825	3.3	6
10	403.190	3.111	9.0	9
8	114.120	43.105	11.0	?[a]
4	263.190	43.532	14.1	7
3	25.270	0.104	14.8	4
1	92.800	4.903	17.0	8
12	145.130	20.035	17.4	8
11	35.267	12.777	20.3	?
7	90.100	32.518	23.3	?
13	455.180	117.175	25.0	?
6	232.000	493.503	25.6	8
9	21.465	8.969	41.0	5
5	191.800	0.255	32.4	4

[a] Indicates patient still not azoospermic as of 10th ejaculate.
Source: Derived from data presented in Ref. [7].

of the ampulla. At one extreme, the ampulla may be highly cavernous with a mucosa consisting of a considerable number of tortuous folds and crevices where sperm can be temporarily entrapped. This type is exemplified by patient 6 in the Freund–Davis series whose remaining sperm was 213% of the number found in his preoperative ejaculate (Table 1); 32%* of the sperm in the prevasectomy ejaculate came directly from the epididymis and 68% from the ampulla. At the other extreme, the ampulla is noncavernous, or nearly so, with a mucosal lining nearly devoid of folds and crevices. In other words, the ampulla has the appearance of a solid-smooth inner surface. This structure is typified by patient 3 in the Freund–Davis series whose remaining sperm account for only 0.13% of the number found in his preoperative ejaculate. His ampulla served almost no storage function at all; 99.9% of the sperm came directly from the epididymis at the time of ejaculation.

Patient 13 falls into an intermediate category in the same series, with 26% of the number of sperm found in his preoperative ejaculate remaining in the tract

* Prevasectomy Specimen total sperm: PSts.
Residual total sperm: Rts.

$$\frac{\text{PSts}}{\text{PSts} + \text{Rts}} \times 100 = \frac{232{,}000{,}000}{232{,}000{,}000 + 493{,}503{,}000} \times 100 = 32\%$$

Table 5

Mean sperm concentration (10^6/specimen)

Preoperative semen specimen	Postoperative semen					
	1	2	3	4	5	6
136.92	53.13	18.41	7.36	2.38	0.78	0.33

Source: See Ref. [8].

following vasectomy. In his case, 79.5% of the sperm in the prevasectomy ejaculate came directly from the epididymis.

These three examples are illustrated in Fig. 2. A preliminary study of actual tissue specimens (ampulla, vas and seminal vesicle) has confirmed that this illustration, based on indirect evidence, is in fact reflected anatomically. Furthermore, a study of 69 asymptomatic men conducted by Banner and Hassler [10], who used vasoseminal vesiculography, showed that there are wide variations in both the internal dimensions and the construction of the ampulla. They state: "The ampulla ranges from 3–7 cm long and 2.7–10.0 mm wide .... The margins of the ampulla may be smooth or serrated, the latter closely resembling many small diverticula. Greater degrees of serration impart a feathery rather than tubular appearance to

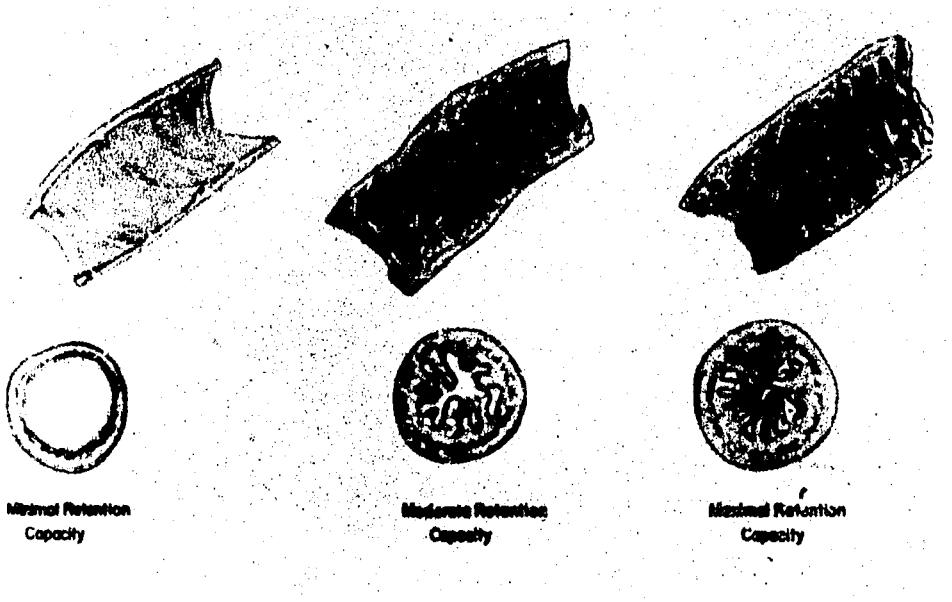


Fig. 2. Longitudinal and transverse cross-section of ampulla of vas: 3 examples

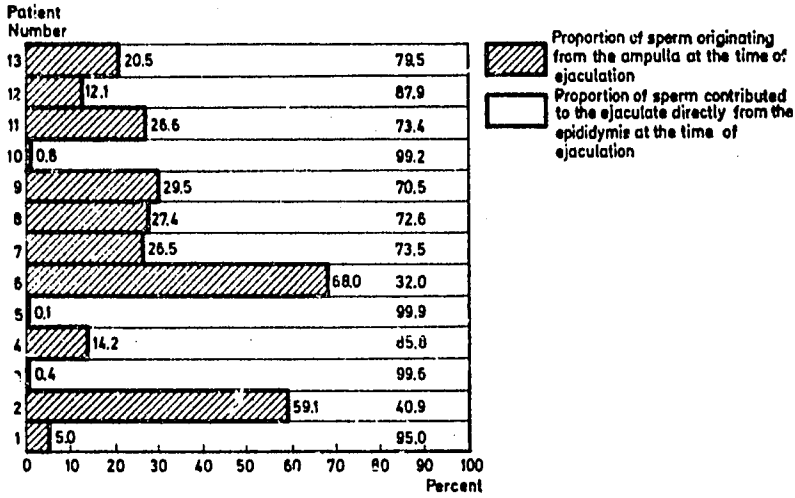
before and after vasectomy (N = 50)

specimens				Total of first ten	Total as per cent of preoperative
7	8	9	10		
0.16	0.17	0.19	0.11	83.02	60.63

the ampulla. Eighty percent of definable ampullae in this series are distinctly tubular and 20% appear feathery. The diameter of the ampullary lumen is never larger than the diameter of the vesicular lumen and is frequently smaller, more so in the serrated variety."

Figure 3 illustrates the wide variations among these 13 men with respect to the proportion of sperm contributed by the ampulla and by the epididymis at the time of ejaculation.

Although it appears that the construction of the ampulla accounts for most of the variation among men, one additional source may be the variation in the amount of fluid contributed to the ejaculate by the vas and its ampulla. The seminal plasma consists of Cowper's gland fluid (0.1–0.2 ml), prostatic secretions



TWO ASSUMPTIONS ARE MADE :

(1) That no sperm were transported from the epididymis to the ampulla during the one to several hours ; [illegible]se between the prevasectomy ejaculation and the vasectomy.

(2) That, on the average, the proportion contributed by the ampulla is constant (otherwise the number of sperm in the ampulla would tend to go to infinity or zero).

Fig. 3. Proportion of sperm originating from the ampulla and the epididyimis at the time of ejaculation

(0.5 ml) and the seminal vesicle secretions that provide the bulk of the ejaculate (2.0–2.5 ml). There are, in addition, extremely small amounts of secretions from the epididymis and the vas deferens, particularly its ampullary portion. Altogether, the ejaculate measures, on the average, 3 ml [11]. However, the range seen in different men is 0.5 ml to 11.0 ml, over a 20-fold difference. This suggests a similar wide variance in the volume of secretions from the vas and its ampulla. Evidently, the greater the volume of vasal and ampullary secretions, the faster azoospermia would be reached.

These wide variations in numbers of remaining sperm and of ejaculations for achieving azoospermia complicate the formulation of a postvasectomy semen examination regimen. This difficulty is exacerbated by the still unanswered, yet relevant and rather basic questions of physiology preventing the formulation of a regimen predicated on medical considerations.

Relevant unanswered basic questions of reproductive physiology

1. What is the minimum sperm count necessary to cause pregnancy?

There is now ample evidence that a sperm count of no more than a few million/ml is sufficient to cause a pregnancy. Data presented at the National Institutes of Health Meeting on Hormonal Control of Male Fertility [12], held in November 1977, conclusively showed that a few million per/ml were adequate in men whose sperm counts were depressed by androgen administration for long periods of time. In two studies by different investigators, sperm counts were continuously monitored in two men to include counts just days before and just days after conception occurred.

There is no evidence that semen specimens with less than one million sperm/ml or even one hundred thousand sperm/ml are *not* fertile. Thus, no minimum sperm count for fertility has been established to date.

2. At what point in time does visualization of only dead (actually immotile) sperm in a specimen ensure that no live sperm remain in the ampulla?

There have been rare cases reported where only dead sperm were observed in one specimen and yet examination of a subsequent specimen showed a small number of live sperm. In the litigious society of the U.S., many physicians are unwilling to declare men sterile unless azoospermia is achieved.

In their series of 76 men, Jouannet and David [9] reported that no motile sperm were found after 15 days postvasectomy. Later, Bedford and Zelikovsky [13] reported that no motile sperm were observed after 19 days postvasectomy in their series of 82 men. However, Edwards [14], in his response to these two articles, states that "My own experience has been that at 3 weeks after vasectomy approximately 5% of men will still have some motile spermatozoa, and that a few will do so to an extreme (so far) of 7 weeks. In all such cases repeat examina-

tion a few weeks later has revealed no motile spermatozoa." In a series of 7000 cases performed at the Planned Parenthood of Houston, one of the authors (S.D.M.) found that approximately 40 men had a few live sperm present in their ejaculate at six weeks to five months postvasectomy. All later became azoospermic. The fact that each of these men experienced a continuous drop in sperm count suggested that recanalization had not occurred in any of these cases. Only the two cases that exhibited a few live sperm at five months postvasectomy have been previously reported [15]. The remainder of these data must be considered anecdotal since the clinic closed in 1977 and the data are no longer assessable.

3. How long can motile sperm stored in the ampulla retain fertilizing capacity and impregnate?

No upper biologic limit has been established. However, there have been several well-documented reports of conceptions as a result of stored sperm occurring six to eight weeks after successful vasectomy [16]. Nevertheless, uncertainty remains regarding the upper time limit.

These fundamental questions must be resolved before a postvasectomy semen examination regimen relying solely on medical considerations can be developed. One exception, of course, would be to base a regimen on extremes, such as requiring three consecutive azoospermic specimens, a process that might extend the testing over the course of more than a year for some men. But even in such instances, the implications of continued use of the pill or an IUD by his partner for the additional year or more should not be ignored.

Detection of recanalization

There are many reports in the literature of early and late recanalizations. Some occur as early as six weeks postvasectomy (as was the case in S.D.M.'s first vasectomy following three weeks of azoospermia). Some surgeons feel that examining the first postvasectomy specimen at three months postvasectomy allows the opportunity to detect most early recanalizations [5]. For example, Planned Parenthood of Houston once reconsidered its policy of waiting three months to examine the first postvasectomy semen specimen. Analysis of the clinic's recanalization cases produced the following findings: In the first 2227 cases performed, ligation of both ends with cotton and excision of 1 cm of the vas was employed. Six of the seven failures were late failures (occurring more than three months postvasectomy) [17]. Application of a Weck clip for occlusion and removal of 1 cm of the vas was then adopted. In the case of the clip, most of the recanalizations (8 of 10 in about 4000 cases) occurred before three months had passed. Upon the presentation of these data to clinic policy makers, it was decided that this opportunity to detect early recanalization alone justified retaining the three-month waiting period [15]. In cases of some occlusion techniques, this consideration is irrelevant

(i.e. the ligature technique mentioned above). This area of study has not been adequately explored. Other physicians may feel that the small risk entailed does not merit such a long waiting period.

Any regimen entails risks, whose existence removes the formulation of a regimen from the strictly scientific to the social sphere. What risks may be taken? How should the values (social) be ranked?

The social considerations

There are social aspects taken into consideration by individual physicians in developing their vasectomy follow-up regimen. It should be remembered that those listed below are not likely to be considered by every physician, and it is probable that the list itself is not all inclusive.

It is recognized that the physician may attempt to minimize:

1. inconvenience to the patient, his partner and to himself (travel, telephone calls, examination of slides, etc.);
2. workload of the clinic and laboratory staff;
3. economic cost of vasectomy follow-up;
4. patient and/or his partner's apprehension about possible pregnancy during the vasectomy/sterility interim, particularly when they have recently switched from a more effective (e.g. pill, IUD) to a less effective method (e.g. condom, foam), a frequently occurring situation;
5. patient and/or his partner's anxiety regarding possible failure of the vasectomy.

The physician may make efforts to maximize:

1. consideration for the health hazards of the partner's continued use of the IUD or pill (particularly when she is already experiencing serious related side effects);
2. opportunities to discover early recanalizations, the majority of which occur in the first several months after the procedure;
3. acceptance of vasectomy in a given population by reducing unattractive features of the vasectomy follow-up regimen.

Formulation of postvasectomy semen examination regimens

Selection of the suitable moment for the first examination of a postvasectomy semen specimen is based either on the time elapsed or on the number of ejaculations postprocedure or both.* A rather wide range of these criteria is used by

* Ejaculation within the first several days following vasectomy is not recommended by the authors. A clinical impression gained during interviews conducted by S. D. M. of Planned Parenthood of Houston Vasectomy Clinic patients who experienced a recanalization revealed that about half had ejaculated within a few days of the vasectomy even though they had been instructed to avoid ejaculation for seven days. The clinic staff postulated that ejaculation before sufficient healing of the stump occurred increased the risk of extravasation of sperm, prompting sperm granuloma formulation that increased the risk of recanalization.

various physicians. The minimum requirement when time alone is the gauge has been reported as four weeks [18] (one third [18] to one half [19] of the men are azoospermic at four weeks). When number of ejaculations is the determining factor, it is six ejaculations [1] (the sixth ejaculate of one fourth to one third of the men is azoospermic [7]). The maximum requirement for the first examination of a postvasectomy semen specimen found in the literature is four months when time alone is used [1] (over 90% are azoospermic at four months [20]), and 20 ejaculations [1] when number of ejaculations is used (approximately 90% of the 20th ejaculates are azoospermic [21]). Combinations are sometimes seen, such as six weeks and ten ejaculations, or three months and 20 ejaculations [21].

The endpoint sought by different physicians before declaring sterility likewise varies. Some feel that a few dead sperm per high power field (HPF) are an adequate demonstration of sterility. Others rely on three consecutive azoospermic specimens collected one month apart. The majority look at a single azoospermic specimen.

Formulation of a postvasectomy semen examination regimen, given the minimum of four weeks or six ejaculations, is based on the social values (considerations) already discussed. Physicians make value judgments, ranking the values according to their own perceptions. For example, if the physician is most concerned about the partner's health and her continued use of the pill or mitigating the patient's apprehension regarding the prospect of failure of the vasectomy and willing to accept some small risk of a stored sperm pregnancy, he will select minimal criteria. On the other hand, a physician who greatly values elimination of any risk of a stored sperm pregnancy, placing little value on other considerations, will select maximal criteria, such as first examining a specimen at four months postvasectomy and then requiring three azoospermic specimens.

Conclusion

There is considerable variation in the disappearance of sperm after vasectomy. Coupled with the very relevant and critical unanswered questions of male reproductive physiology, formulation of a postvasectomy semen examination regimen based on biologic considerations alone is not currently possible. Social (nonmedical) considerations necessarily play a substantial role in this process. No single set of criteria is "better" than all others. No one can soundly argue that any one regimen is superior to another until our understanding of male reproductive physiology is far more complete. The setting of a particular standard for declaring sterility postvasectomy other than azoospermia in at least one semen sample does not appear to be defensible.

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