Development of a Mechanical Model of the Lumens of the Male Reproductive Tract

(Technical Research Paper)

Barriers To Long-Term, Semi-Permanent Male Contraceptives and Male Involvement in Reproductive Health

(Sociotechnical Research Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignment

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Introduction

How is birth control represented among men?

Progestin-Only pills, intrauterine devices, and vaginal rings are common examples of modern long-term, semi-permanent contraceptives—for women. On the current open market, no semi-permanent devices exist for men. The first long-term contraceptive was created in 1953 that targets progesterone and estrogen ("A Brief History of Birth Control," n.d.) in the female body. Since then, dozens of new long-acting contraceptives for women have been created. 70 years later, there is still yet to be a long-term, semi-permanent choice for men. While vasectomies, a form of male birth control that cuts off the supply of sperm to your semen, are technically reversible, multiple factors determine the viability of a reversal, such as the time passed since the reversal, and the age at which the vasectomy occurred. Reversals also do not guarantee fertility. If done in three to five years, 88 percent of patients achieve sperm in the semen, but only have an average pregnancy rate of 53 percent ("Vasectomy Reversal," n.d.). Passed this timeline, fertility continues to decrease, with a success rate of 40% to as low as 25% (Fuchs, n.d.).

Contraline, Inc., a biotechnology company in Charlottesville, VA, hopes to be the first to bring contraception of this type to market. Contraline has begun the development of a non-hormonal long-acting reversible contraceptive (LARC) involving a hydrogel inserted into the vas deferens that is designed to block sperm from traveling through without affecting sensation or ejaculation (*Contraline*, n.d.). The technical research will focus on the development of a mechanical model of the lumen, the hollow center of the tubule of the vas deferens, to aid in the testing and validation of the ADAM™, Contraline, Inc.'s novel LARC. The sociotechnical research that follows will focus on the barriers of LARC for men as well as the barriers of the involvement of men in the uptake of contraceptives in the United States. With the potential of a

new contraceptive, it is important to understand and evaluate the pushback of the last half century regarding male reproductive health.

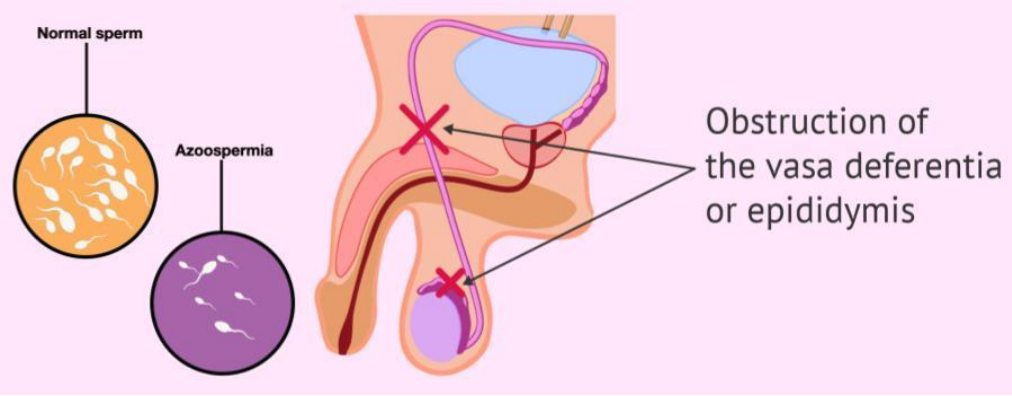
Technical Discussion

Developing a Mechanical Model of The Inner Lumen of The Male Reproductive Tract

How does the vas deferens contract and expand in reaction to stimuli?

The current widespread, long-term "reversible" contraceptive for men on the market is a vasectomy. A vasectomy requires incising the scrotum and withdrawing part of the vas deferens through the incision to cut and seal it via cauterization, surgical clips or combination of methods (*Vasectomy - Mayo Clinic*, n.d.). The incision is then either closed via stitches or glue, or simply left to heal naturally. This process will cause a phenomenon called post-testicular obstructive azoospermia, a blockage or missing connection along the reproductive tract that causes a "zero sperm count," a lack of measurable sperm in ejaculation (see Figure 1). Contraline, Inc. has been

Figure 1: Diagram of Azoospermia



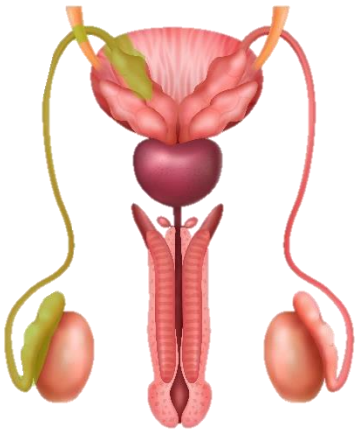
A visual representation of obstructive azoospermia in which sperm cannot travel through the reproductive tract due to a blockage (*Azoospermia*, n.d.). A visual comparison of the sperm counts between normal patients and azoospermia patients (*Male Infertility (Azoospermia) Diagnosis and Treatment*, n.d.).

working to develop a non-hormonal, minimally invasive version of birth control that does the same as a vasectomy by inserting a hydrogel into the vas deferens, the pair of tubes that transport

sperm, of the male reproductive tract. This hydrogel will block sperm from traveling out, keeping the sperm where it can naturally degrade and absorb into the body. Eventually, at the end of its use, the hydrogel will dissolve, flowing out of the vas deferens with ejaculation, allowing for sperm to resume flow.

Contraline, Inc. requires a viscoelastic model of the inner tract of the vas deferens, that travels from the epididymis, which lays along the testicle, to the ejaculatory duct, which leads to the urethra, (see Figure 2) that dynamically responds to pressure and manipulation in order to further test the device. Currently, Contraline, Inc. uses simple tubing, with dimensions comparable to the dimensions of the vas deferens. However, this tubing lacks the proper

Figure 2: Model of Male Reproductive Tract

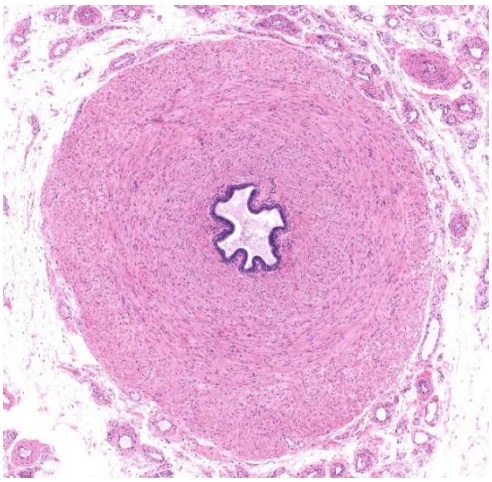


A visual representation of the male reproductive tract, highlighting the region of the lumen, from the epididymis to the ejaculatory duct, required in the mechanical model (MacroVector, n.d.).

elasticity and response to stimuli, as well as being an overall simplified shape of the lumen. A previous model that attempted to improve upon the silicon tubing was made from an elastomer with optical, electrical, and mechanical properties, called Polydimethylsiloxane or PDMS, due to its biocompatibility (Miranda et al., 2021). However, previous testing showed that PDMS lacked the proper Young's Modulus when compared to the vas deferens. This suggests that rather than

be a single material, such as PDMS in different hardener ratios, the best representation of the vas deferens will be derived from a composition of materials with the same biocompatibility as PDMS, but with greater stiffness and elasticity. Combining materials would likely be the most effective method, however, with the difficulty of combining two resin materials, the easier solution would be to increase the thickness of the tubing to mimic the radial stiffness without compromising the elasticity. This tubing will be made using a FormLabs Form 3+ stereolithography resin 3D printer. The required use of this printer leads to problems in regard to the feasibility of mimicking the shape of the lumen. While the outer vas deferens has a rather uniform circular shape, the inner lumen has an unconventional, irregular shape (see Figure 3), making it hard to replicate. Thus, while the aim is to develop a mechanically and physically accurate model, the former may be easier to achieve. A stereolithography resin 3D printer works by using an ultraviolet laser light to solidify a liquid curable photopolymer into the shape of the input design, starting from the top of the design to the bottom, building upside down. With the combination of the constraints of the printer, and the constraints of the material, developing a

Figure 3: Histology Image of the Vas Deferens



Histology slide of the vas deferens, or ductus deferens, indicating the thickness of the vessel wall in comparison to the thickness of the lumen. This slide demonstrates the non-polygonal nature of the lumen (Wilk-Blaszczak, n.d.).

mechanical model of the male reproductive tract will prove difficult. However difficult, a model such as this one is the gateway to normalizing the world of male contraceptives.

STS Discussion

Barriers To Long-Term, Semi-Permanent Male Contraceptives and Male Involvement in Contraceptive Uptake in The United States

Why is there a lack of resources for men?

The lack of long-term, reversible contraceptives for men is a result of the barriers blocking this form of contraception as well as the barriers inhibiting male involvement in the growth of long-term contraceptives. NPR has noted that a barrier toward the development of hormonal male contraceptives is the complexity of the male reproductive tract. Women typically release one or two eggs per month, requiring only the regulation of hormones during this time period. Men, however, can produce millions of sperm per day, and a single ejaculation contains 15 million sperm per milliliter of semen (Barber & Muraskin, 2022). Regulating the count of sperm to reliably prevent pregnancy would require constant manipulation of male hormones, which can become an issue of safety, but also one of ethics. The hormonal methods of male birth control consists of a gel applied to the skin, an injection into muscle, or perhaps a pill, containing testosterone as well as progestin, a form of progesterone, the hormone that plays a role in the menstrual cycle in women (Chung-Lun Wang, 2022). While progesterone is beneficial for men in reducing stress and helps balance the body, excessive progesterone can wreak havoc on the body causing estrogen dominance (Lam & Lam, n.d.). Estrogen dominance can result in the feminization of men as well as erectile dysfunction, prostate enlargement, and increased risk of prostate cancer. Thus, even though a hormonal male birth control such as this can suppress sperm production, it can also have some potential negative long-term side effects.

Since contraception is not used to treat a disease, it is imperative that the side effects of these methods are minimal and short-term in order to be acceptable to the target population (Plana, 2015). Along with the possibility of estrogen dominance, many male hormonal birth controls cause depression. This occurs in female hormonal birth controls as well; however, depression has become somewhat normalized in female reproductive health. Men, though, deny having depression because they discover early on that acknowledging emotional pain is a sign of weakness and find it shameful (Schlossberger, 2021). Thus, many clinical trials for male contraceptives with the depression side effect cause concern from the general population and are terminated. With male birth control being so novel, there have not been many studies on the long-term effects of contraceptive methods due to the limited amount of research. The lack of research leads to a lack of acceptability of male contraception. However, acceptability only comes with studies and research, creating an endless loop. So, that begs the question, how can it be broken?

Regarding male involvement, BMC Public Health investigated these barriers, citing reluctance and shamefulness, as well as overall misperceptions (Roudsari et al., 2023), due to the institutionalization of reproductive health as women's health. Understanding these barriers to male reproductive health will allow companies to better approach these issues and break into the male contraceptive market. With the idea family planning and pregnancies are for women, there is an inadequate amount of family education targeted for men's participation. With the lack of awareness for men in reproductive services, it leads to a lack of training and a lack of encouragement to participate. The reluctance of women to involve men is also a cause for concern. Some women prefer to attend health centers alone or learn about reproductive health alone due to issues such as feminine embarrassment, fear of the partner, and the ignorance of

men to the situation at hand. This leads back to the idea of the endless loop. Men do not get involved because of a lack of awareness, and some women do not want men to be involved because they are unaware.

Conclusion

While the contraceptive world has grown a lot over the last fifty years, there is still a long way to go. There are far too many barriers blocking men from participating in their own reproductive health, as well as too many barriers blocking companies to aid in men's participation in reproductive health. It is with hope that this model of the male reproductive tract will allow Contraline, Inc. to break down these barriers and open the doors to male contraceptives. And with awareness, the rest of the barriers will be brought down with it.

[1794 words]

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