Seminal Vesicles

3

Surabhi Gupta, Mona Sharma, and Anand Kumar

Learning Objectives

- Gross anatomy and development
- Maturation and involution
- Microstructure and function
- Hormonal regulation
- Disorders

3.1 Introduction

Berengario da Carpi, an *Italian* anatomist gave the first ever report on seminal vesicles in 1521. He regarded them as storage organs for semen. Various morphological studies have suggested that the seminal vesicles along with the ampulla of the ductus deferens and the ejaculatory ducts function as a single unit known as ampullovesiculoductal complex (Riva et al. 1989).

S. Gupta, PhD (✉) • M. Sharma, MD, DNB, MAMS
A. Kumar, MD, FAMS
Department of Reproductive Biology, All India Institute of Medical Sciences, New Delhi, India
e-mail: surabhi72@rediffmail.com

A. Kumar, M. Sharma (eds.), *Basics of Human Andrology*,
DOI 10.1007/978-981-10-3695-8_3

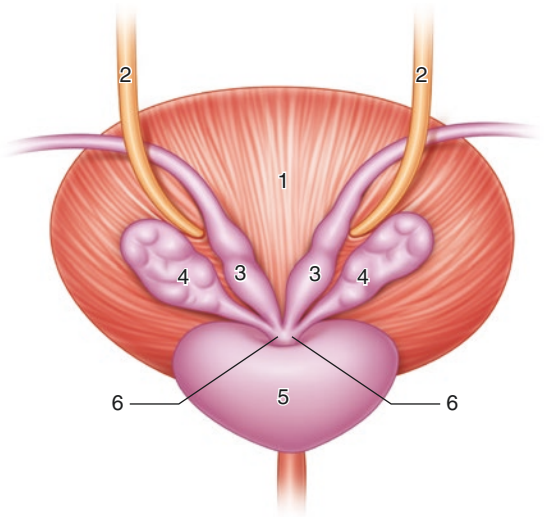

Fig. 3.1 Schematic diagram (posterosuperior view) showing anatomical relations of seminal vesicles: *1* urinary bladder, *2* ureters, *3* ductus deferens, *4* seminal vesicles, *5* prostate gland, *6* ejaculatory ducts

3.2 Gross Anatomical Features

The seminal vesicles or glandulae vesiculosae or vesicular glands are a pair of simple tubular glands located between the bladder anteriorly and rectum posteriorly (Frandson et al. 2009). The vesicles are blind pouches and are rounded on their most superior aspects and taper to their inferior aspects, where they constrict to ultimately form short ducts. Each seminal vesicle is a single-coiled tube of approximately 5 cm length with irregular folds in the lumen. The full unfolded length of seminal vesicle is approximately 10–15 cm. They descend inferomedially while lying on the posterior surface of the urinary bladder (see Fig. 3.1). The dilated portion or ampulla of the vas deferens lies along the medial margin of each seminal vesicle. The veins of the prostatic venous plexus are related lateral to it. The duct of seminal vesicle joins the distal portion of the vas deferens and becomes the ejaculatory duct, which drains into the prostatic urethra (Standring 2005a).

3.3 Development

Developmentally, when the testes begin to form during intrauterine life, the mesonephric or Wolffian duct differentiates into the male genital system under the influence of testosterone. Initially, the seminal vesicle and ductus/vas deferens form a common swelling which later during fourth month, gets separated into two structures. Mesonephric duct ultimately forms the epididymis, ductus deferens, seminal vesicle, and ejaculatory duct. (see Fig. 3.2, Standring 2005b).

The growth and differentiation of the seminal vesicle continues until birth, and the interior of the gland forms mucosal folds and ridges, as well as smooth muscle

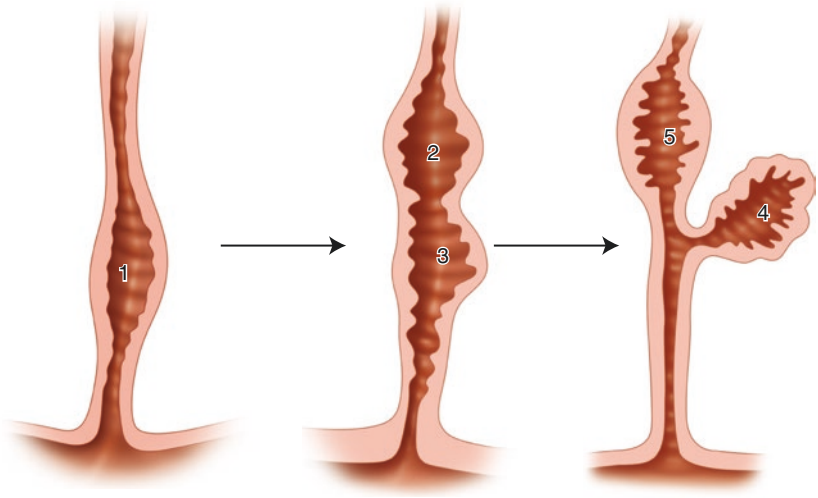

Fig. 3.2 Schematic diagram showing development of seminal vesicles. Mesonephric duct forming a common swelling (*1*) which later divides into two swellings (*2*, *3*); the swelling that grows laterally forms the seminal vesicle (*4*) whereas the other one forms ductus deferens (*5*)

Table 3.1 Maturation stages of seminal vesicles

Age (years)	Neonatal	1	1–5	8–14	15
Weight (gm)	0.05	0.08	0.09	0.1–0.15	1.5
Length (mm)	10	15	17	20–25	61
Width (mm)	3.3	4	4	4	6.6

cells differentiate in two layers within the seminal vesicle wall. The distal end of the vas deferens develops into the ampulla. The prostatic tissue surrounds the terminal portion of the mesonephric duct and forms the ejaculatory duct.

3.4 Maturation and Involution

Until puberty, growth of seminal vesicles proceeds slowly (see Table 3.1, Aumuller and Riva 1992). In children, the mucosal epithelium of the seminal vesicles consists of glandular and basal cells. The glandular weight increases during puberty. The gland develops typical mucosal folds projecting into the lumen. Connective tissue and smooth muscle cells increase in amount. Following this, the glandular epithelium becomes secretory. After 45 years of age, the regressive changes start with respect to the glandular and muscular contents of the vesicles. The smooth muscle content of the organ is reduced because of atrophic changes. There is decrease in secretion by the glandular cells, degeneration of the connective tissue, and decrease in number of mucosal folds. The overall volume of seminal vesicles is reduced (Aumuller and Riva 1992).

3.5 Microstructure

Seminal vesicles are the elongated coiled tubes having mucosal folds which projects into the lumen. The wall of seminal vesicle is composed of three coats: an internal or mucous coat, middle or muscular coat, and an external connective tissue coat or adventitia (see Fig. 3.3).

The mucous coat consists of interconnected folds which significantly increase the surface area. The folds are the primary folds which further branch into secondary folds. The folds are lined by pseudostratified columnar epithelium which consists of tall, columnar secretory cells and short, round basal cells that are the stem cells. The height and activity of the columnar cells depend on the blood testosterone levels. The lumen of the seminal vesicle is large and fluid secretions are stored there in between ejaculations.

The lamina propria is a loose connective tissue layer which extends into the folds. It consists of smooth muscle cells and elastic fibres. It is surrounded by inner circular and outer longitudinal layers of smooth muscles which are not clearly distinguished because of extensive mucosal folds. During ejaculation, smooth muscle contractions discharge the fluid produced by the seminal vesicles into the ejaculatory ducts and sperm out of the urethra. The smooth muscle layer is surrounded by connective tissue of the adventitia (Ross and Pawlina 2011).

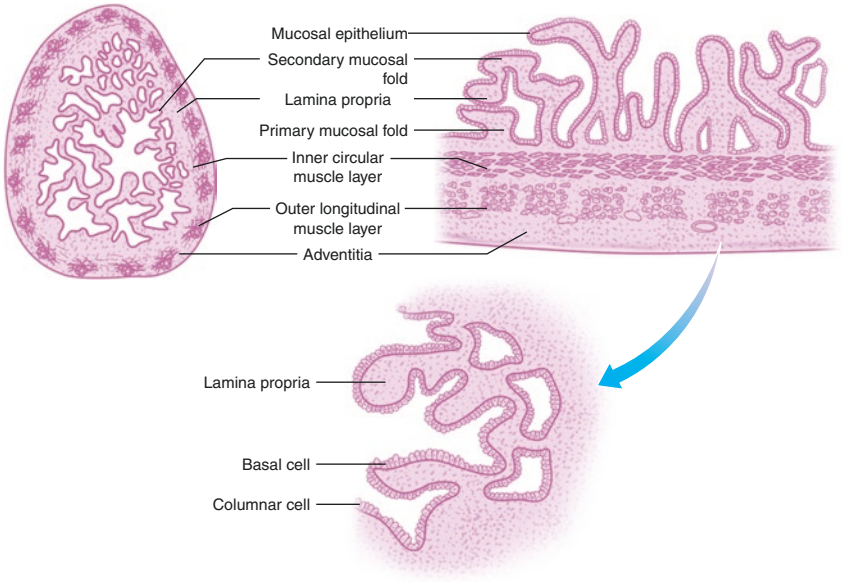

Fig. 3.3 Schematic diagram showing microstructure of seminal vesicle

3.6 Functions

The main function of the seminal vesicles is to produce components of the seminal plasma. The seminal plasma acts as a natural diluent and transport vehicle for the sperm. It also assists sperm passage through the male and female reproductive tract by eliciting smooth muscle contractions in both. Though it appears in the later fractions of ejaculation, seminal vesicle secretions form the largest portion (~65–75%) of a typical human ejaculate (Drabovich et al. 2014). The normal secretion of the seminal vesicle is alkaline which is important for protecting the sperm from the acidic vaginal environment. It has a whitish yellow colour due to the presence of fluorescent flavins (Burgos 1974).

The important constituents of seminal plasma secreted by the seminal vesicle include fructose, semenogelin I and II, prostaglandins, citric acid, ascorbic acid, ergothioneine, potassium ions, and inorganic phosphorus.

The seminal plasma has a high concentration of reducing substances belonging to two groups: one made up of molecules such as ergothioneine and ascorbic acid, the other being carbohydrates. The most important free carbohydrate secreted by seminal vesicles is fructose with the others being inositol, glucose, ribose, fucose, and sorbitol which are secreted in small amounts (Mann 1964). Fructose is found at a concentration of 200 mg/dl in the semen. It originates from the blood glucose and three different metabolic pathways for its biosynthesis have been proposed (Mann and Lutwak-Mann 1981). These are (i) glycogenolysis, (ii) direct phosphorylation to form glucose-6-phosphate, and (iii) non-phosphorylative pathway via formation of sorbitol (see Fig. 3.4).

Fructose is the primary energy source for the sperm following deposition of sperm in the female genital tract. Since hypoxic conditions are present in the vagina, fructose undergoes anaerobic degradation or fructolysis to produce lactic acid and

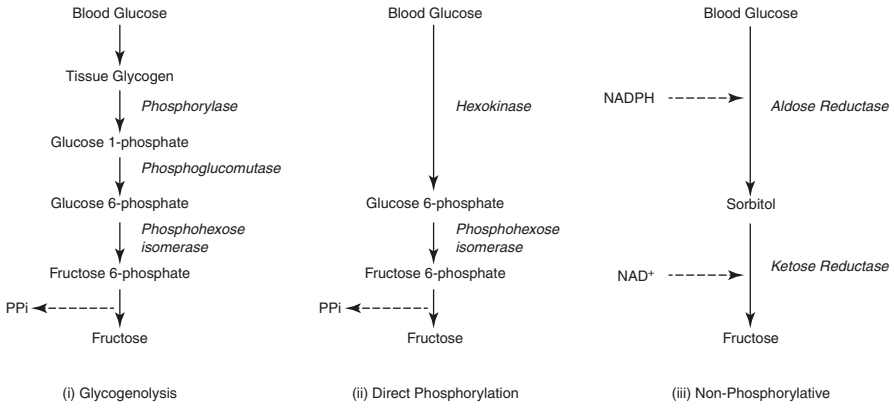

Fig. 3.4 Flow chart showing biosynthesis of fructose from blood glucose by seminal vesicles

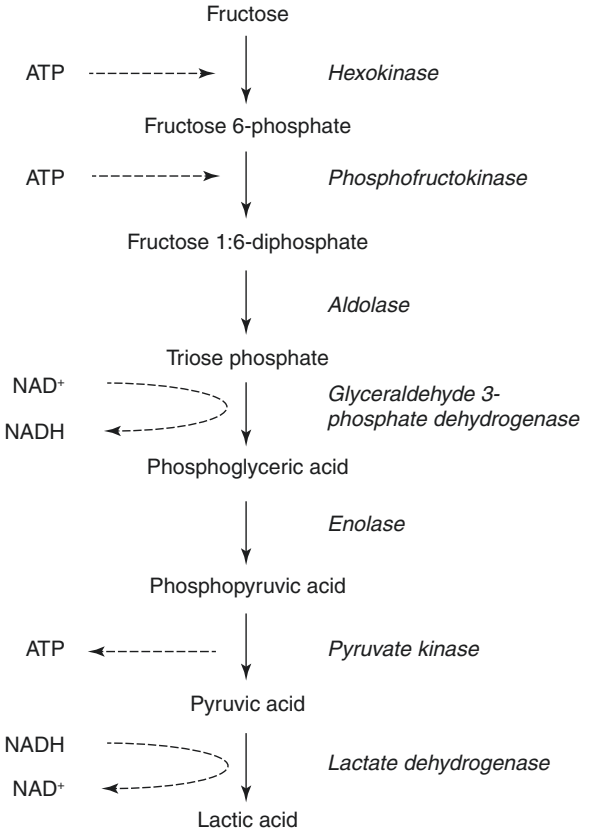

Fig. 3.5 Flow chart showing fructolysis by mammalian sperm

adenosine triphosphate (ATP; see Fig. 3.5). A positive correlation exists between the rate of fructolysis and the degree of sperm motility (Peterson and Freund 1976). In fact, if sperm are immobilized with a spermicidal agent, they immediately and irreversibly lose their fructolytic ability (Mann et al. 1980).

Seminal plasma has the highest levels of prostaglandins among all body fluids in humans. About 15 different prostaglandins are produced by the seminal vesicle; the main being PGE-1, PGE-2, and their 19-hydroxylated derivatives: 19-OH PGE-1 and 19-OH PGE-2. Prostaglandins stimulate the smooth muscle contractions in the reproductive tracts of both male and female. In males, they affect the processes of erection, ejaculation as well as testicular and penile contractions. While in females, these seminal fluid prostaglandins affect the cervical mucus, vaginal secretions, and induce uterine contractions, thereby helping the sperm to move in the female reproductive tract.

Another important product of seminal vesicles is semenogelins which are needed for semen coagulation. Details of semen coagulation are given in the chapter, The Human Semen. Semenogelins account for up to 30% of all seminal plasma proteins (Drabovich et al. 2014). Though the precise physiological importance of semen coagulation is not known, it results in coating the sperm surface with many molecules which may help in the natural process of fertilization.

The components of seminal plasma may not be absolutely essential for successful fertilization as sperm taken from epididymis or even testis can be used for fertilizing an egg. However, under natural course, the seminal fluid and its constituents optimize the conditions for sperm transport through the female reproductive tract and hence, increase the chances of successful fertilization.

3.7 Hormonal Regulation

The development as well as secretory function of the seminal vesicle is under androgen control. The secretory activity can serve as a measure of androgen supply to the organ (Mann and Lutwak-Mann 1981). Castration results in cessation of the secretory activity within a few hours and start of the involution process in the seminal vesicles and other accessory sex organs (Aumuller and Seitz 1990). Exogenous testosterone given to the castrated animals can fully restore the involuted organs in both size and secretory function. This reversible regression of the accessory sex organs occurs naturally in seasonally active males, such as deer and sheep. In humans, involution of the gland can result from anti-androgen treatment also.

Male pseudo-hermaphrodites with deficiency of the 5-alpha reductase 2 enzyme have low semen volume and high seminal viscosity (see chapter, Prostate for details; Cai et al. 1994). Since seminal vesicles are responsible for producing about 65–75% of the total semen, the low semen volume indicates hypofunction of the seminal vesicles.

Both testosterone and luteinizing hormone (LH) increase the weight of seminal vesicles when given to prepuberal rats (Foreman and Weeks 1978). The action of LH maybe through testosterone or direct but no research has been done to delineate this.

Intraperitoneal injection of oxytocin in mouse reduces fructose concentration in the seminal vesicle. However, circulating levels of glucose and testosterone, both of which are required for fructose synthesis, remain unaltered indicating a direct effect of oxytocin (Kumar and Farooq 1994).

The proliferative actions of androgens are enhanced by prolactin in the mouse seminal vesicles by increasing its weight as well as DNA levels. This effect of prolactin was not seen in castrated mice; however, androgenic stimulation was enhanced if prolactin and testosterone were administered simultaneously. The mechanism for this is not well understood but prolactin neither increases androgen accumulation nor enhances conversion of testosterone to dihydrotestosterone (DHT) (Thomas and Keenan 1976; Keenan et al. 1981).

3.8 Disorders

Congenital abnormalities of the seminal vesicle are rare and include agenesis and cysts, while the acquired diseases include tumors and inflammation.

3.8.1 Seminal Vesicle Agenesis

Defects in the embryonic development of the mesonephric duct or CFTR gene mutations can lead to congenital seminal vesicle agenesis. Seminal vesicle agenesis always occurs in association with unilateral or bilateral agenesis or ectopic presence of the vas deferens (Wu et al. 2005). Some cases also present with unilateral renal agenesis, possibly arising if the insult to the mesonephric ducts occurred prior to 7 weeks of gestation, i.e. before ureteral budding (Arora et al. 2007). About 80–95% of men with CFTR gene mutations show bilateral agenesis of vas deferens or seminal vesicles (Kavoussi and Costabile 2012). Infertility is the major symptom associated with seminal vesicle agenesis even though testicular spermatogenesis is intact (Bouzouita et al. 2014).

3.8.2 Seminal Vesicle Cyst

Seminal vesicle cysts can be congenital or acquired. Congenital cysts are mostly solitary but may also be associated with upper urinary tract abnormalities or polycystic kidney disease, an autosomal dominant genetic disorder. They are usually detected in men in their twenties or thirties, possibly coinciding with the onset of sexual activity. About two-thirds of the patients with seminal vesicle cysts also have unilateral renal agenesis or dysplasia. This may reflect maldevelopment of the distal mesonephric duct and improper ureteral budding (Arora et al. 2007). Inflammation and obstruction of ejaculatory ducts, caused by urinary infection or calculi, are associated with acquired seminal vesicle cysts.

3.8.3 Seminal Vesicle Tumors

Though primary tumors of the seminal vesicle are rare, secondary involvement of seminal vesicles in the malignant spread of carcinoma of prostate, bladder, or rectum or from lymphoma has been reported (Kavoussi and Costabile 2012). Most primary tumors of seminal vesicle are carcinomas. The glycoprotein CA-125 can be used as a tumor marker in these patients as its serum levels correlate well with the clinical course of the disease (Thiel and Effert 2002).

3.8.4 Inflammation of Seminal Vesicle

Seminal vesiculitis or inflammation of the seminal vesicles can be caused by bacteria commonly found in urogenital infection. Often vesiculitis is seen in combination with prostatitis and can result in abnormal semen parameters (Behre et al. 2010). Recently, low expression of semenogelin I has been seen in association with seminal vesiculitis pointing to an antibacterial role for semenogelin (Liu et al. 2016).

Key Questions

- At which stage of life do the development, maturation, and involution of seminal vesicles take place?
- What are the key components of seminal plasma produced by the seminal vesicles?
- Describe the physiological functions of fructose, prostaglandins, and semenogelin in the seminal plasma.
- Discuss the hormonal regulation of seminal vesicles.

References

Arora SS, Breiman RS, Webb EM, Westphalen AC, Yeh BM, Coakley FV. CT and MRI of congenital anomalies of the seminal vesicles. AJR Am J Roentgenol. 2007;189:130–5.

Aumuller G, Riva A. Morphology and functions of the human seminal vesicle. Andrologia. 1992;24:183–96.

Aumuller G, Seitz J. Protein secretion and secretory processes in male accessory sex glands. Int Rev Cytol. 1990;121:127–231.

Behre HM, Nieschlag E, Weidner W, Wieacker P. Diseases of the seminal ducts. In: Nieschlag E, Behre HM, Nieschlag S, editors. Andrology: male reproductive health and dysfunction. Heidelberg/New York: Springer; 2010. p. 263–78.

Bouzouita A, Kerkeni W, Abouda H, Khrouf M, Elloumi H, Mnif N, et al. Seminal vesicle agenesis: an uncommon cause of azoospermia. Can Urol Assoc J. 2014;8:E266–9.

Burgos MH. Biochemical and functional properties related to sperm metabolism and fertility. In: Brandes D, editor. Male accessory sex organs: structure and function in mammals. New York: Academic Press; 1974. p. 151–60.

Cai LQ, Fratianni CM, Gautier T, Imperato-McGinley J. Dihydrotestosterone regulation of semen in male pseudohermaphrodites with 5 alpha-reductase-2 deficiency. J Clin Endocrinol Metab. 1994;79:409–14.

Drabovich AP, Saraon P, Jarvi K, Diamandis EP. Seminal plasma as a diagnostic fluid for male reproductive system disorders. Nat Rev Urol. 2014;11:278–88.

Foreman D, Weeks J. Decreased fructose concentrations in coagulating glands of prepuberal rats treated with testosterone and LH. Horm Res. 1978;9:225–35.

Frandson RD, Wilke WL, Fails AD. Anatomy and physiology of farm animals. 7th ed. Wiley-Blackwell: Ames; 2009.

Kavoussi PK, Costabile RA. Surgery of the scrotum and seminal vesicles. In: McDougal WS, Wein AJ, Kavoussi LR, Novick AC, Partin AW, Peters CA, Ramchandani P, editors. Campbell-Walsh urology tenth edition review. Philadelphia: Saunders; 2012. p. 190–4.

Keenan EJ, Klase PA, Thomas JA. Interaction between prolactin and androgens in the accessory sex organs of male mice. J Endocrinol. 1981;90:323–30.

Kumar A, Farooq A. Effect of oxytocin on the concentration of fructose in the accessory glands of mouse. Life Sci. 1994;55:PL19–24.

Liu B, Song Z, Su S, Tang M, Xu A, Song N, et al. Abnormal expression of Sg I is closely related to seminal vesiculitis. Urology. 2016;88:227 e9–e14.

Mann T. The biochemistry of semen and of the male reproductive tract. London/New York: Methuen/Wiley; 1964.

Mann T, Lutwak-Mann C. Male reproductive function and semen: themes and trends in physiology, biochemistry, and investigative andrology. Berlin/New York: Springer; 1981.

Mann T, Jones R, Sherins RJ. Fructolysis in human spermatozoa under normal and pathological conditions. J Androl. 1980;1:229–33.

Peterson RN, Freund M. Metabolism of human spermatozoa. In: Hafez ESE, editor. Human semen and fertility regulation in men. Saint Louis: Mosby; 1976. p. 176–86.

Riva A, Usai E, Scarpa R, Cossu M, Lantini MS. Fine structure of the accessory glands of the human male genital tract. In: Motta PM, editor. Developments in ultrastructure of reproduction: progress in clinical and biological research. New York: Liss; 1989. p. 233–40.

Ross MH, Pawlina W. Histology: a text and atlas: with correlated cell and molecular biology. 6th ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2011.

Standring S. Accessory glandular structures. In: Standring S, editor. Gray's anatomy: the anatomical basis of clinical practice. Edinburgh/New York: Elsevier Churchill Livingstone; 2005a. p. 1319.

Standring S. Development of the urogenital system. In: Standring S, editor. Gray's anatomy: the anatomical basis of clinical practice. Edinburgh/New York: Elsevier Churchill Livingstone; 2005b. p. 1373–95.

Thiel R, Effert P. Primary adenocarcinoma of the seminal vesicles. J Urol. 2002;168:1891–6.

Thomas JA, Keenan EJ. Prolactin influences upon androgen action in male accessory sex organs. Adv Sex Horm Res. 1976;2:425–70.

Wu HF, Qiao D, Qian LX, Song NH, Feng NH, Hua LX, et al. Congenital agenesis of seminal vesicle. Asian J Androl. 2005;7:449–52.