EDUCATIONAL COMMENTARY – SPERM MORPHOLOGY

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Learning Outcomes

Upon completion of this exercise, the participant will be able to:

- Use the Adelman/Cahill system to identify sperm abnormalities based on a definitive characteristic or location that identifies the actual nature of the abnormality as opposed to the use of vague terms such as "amorphous."
- Use common descriptive terminology that aids in consensus among microscopists from different institutions in their assessment of sperm morphology.

Sperm morphology is an integral part of a routine semen analysis. Historically, there has been little consensus in terminology to assess sperm abnormalities. There are currently 3 commonly used classification systems: the Adelman/Cahill,\textsuperscript{1,2} Strict,\textsuperscript{3,4} and WHO\textsuperscript{5} approaches. The Adelman/Cahill approach defines abnormalities using commonly known descriptive terminology that the microscopist can apply to the sperm seen using the light microscope.

[continued on next page]
The Normal Sperm

Figure 1 displays a normal sperm as seen using a light microscope.

(Rerproduced with permission from Adelman MM, Cahill EM. *Atlas of Sperm Morphology*. Chicago, IL: ASCP Press, 1989; 15.)

The normal sperm is a free swimming cell. It consists of 2 portions, a flattened oval head that contains the paternal genetic material and a tail that propels the sperm in a vigorous forward motion to enable penetration of the egg.
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The normal sperm head is oval in appearance as seen from the front and pear-shaped when viewed from the side. It consists of 2 main regions demarcated by a transverse line. It is approximately 4-5 µm long and 2-3 µm wide at the transverse line. The lighter staining anterior region of the head, designated as the acrosomal region, consists of the acrosomal cap that covers the anterior 2/3 of the nucleus and ends at the transverse line. The acrosomal cap provides enzymes to aid in the penetration of the egg. The darker staining posterior region of the head, designated as the postacrosomal region, contains the nucleus that arches up into the acrosome. The nucleus comprises 65% of the sperm head and contains the paternal genetic material. The anterior portion of the nucleus is not visible because it is covered by the acrosomal cap.

The normal sperm tail is about 50-55 µm long and varies in thickness from 1 µm at the midpiece to 0.1 µm at the endpiece. It consists of an axial core complex, the axoneme, which is surrounded by various sheaths. The axoneme contains 2 central singlet microtubules, surrounded by 9 pairs of doublet microtubules, and an outer ring of 9 dense fibers. Four regions of the tail can be differentiated by light microscopy due to slight variations in thickness of the tail in each section due to the different sheaths that surround the axoneme in a particular section.

The normal neckpiece is barely discernible and attaches the head to the tail. An abnormally long neckpiece kinks and allows the head to fall back upon the tail causing the sperm to propel itself in circles or drag the poorly supported head backwards.

The midpiece, the thickest portion of the tail, is 5-8 µm long and 1 µm thick. The midpiece is the thickest portion of tail because in this region the axoneme is surrounded by a mitochondrial sheath that produces metabolic enzymes required for motility. The mitochondrial sheath ends abruptly at the annulus.

The mainpiece, about 45 µm long and 0.5 µm thick, begins at the annulus. In this section, the 9 dense fibers gradually diminish and disappear leaving only the axoneme surrounded by a fibrous sheath. The fibrous sheath ends abruptly leaving the endpiece that has no sheaths. The endpiece is 5-7 µm long.

The Abnormal Sperm

Abnormalities of the head:
The Adelman/Cahill approach classifies head abnormalities by descriptive characteristics and location of the defect. A malformation of the anterior portion of the head is considered an acrosomal abnormality, whereas a malformation of the posterior region (postacrosomal region) is a nuclear abnormality.
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Malformations in the acrosomal region designated as *acrosomal abnormalities* are seen in Figure 2:

Figure 2: (Note: Tails have been shortened)

A. Vacuolation in which 3 or more bubble- or hole-like vacuoles are present in the acrosome
B. Acrosomal deficiency in which the acrosome portion is visible on less than 1/2 of the head giving the sperm head a pointed appearance
C. Acrosomal deficiency in which the acrosome is totally missing

Malformations in the postacrosomal region designated as *nuclear abnormalities* are seen in Figure 3:

Figure 3: (Note: Tails have been shortened)

A. Elongated postacrosomal region (nuclear abnormality)
B. Flattened postacrosomal region (nuclear abnormality) resulting in an acorn-like appearance
C. Elongated postacrosomal region (nuclear abnormality)
D. Vacuolation in which there are 3 or more bubble- or hole-like vacuoles in the postacrosomal region

Sperm also vary in size. A sperm head that is smaller than 4-5 µm long and 2-3 µm wide is termed a *microsperm*. Conversely, a sperm that is larger than the above dimensions is a *macrosperm* (or *megalosperm*). Size variation is displayed in Figure 4:
Paired sperm present as "two-headed" sperm. Pairing is the result of errors in maturation or is 2 immature sperm that have not completely separated during spermatogenesis. Since two-headed sperm cannot penetrate the egg under normal circumstances, it suffices to classify all of them under the same heading of "pairing." Errors in maturation may be of great significance in cutting-edge IVF technology, but this is beyond the scope of a "routine" semen analysis. Pairing is seen in Figure 5:

Abnormalities of the tail:
The Adelman/Cahill approach classifies tail abnormalities by descriptive characteristics and location of the defect. Tail abnormalities occur as the result of aberrations of the various sheaths and/or absence or disorganization of the various elements of the axoneme. The most commonly seen abnormalities are: coiling of the tail, kinking of the neckpiece or midpiece, multiple tails, and shortening of the tail. These abnormalities result in diminished motility and/or the inability of the sperm to propel itself in a vigorous forward motion. Tail abnormalities are seen in Figure 6:
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Figure 6: (Note: Tails have been shortened)

A. Lengthened neckpiece resulting in a kink
B. Kinked midpiece
C. Coiled tailpiece
D. Coiled tailpiece with abnormal midpiece enabling tail to encircle the sperm head
E. Coil at the endpiece
F. Multiple tails emerging from an abnormal disorganized neckpiece

Abnormal sperm that display more than one abnormality can result in bizarre forms. Sperm with multiple defects are seen in Figure 7:

Figure 7: (Note: Tails have been shortened)

A. Acrosomal deficiency and nuclear abnormality resulting in bullet-like appearance
B. Acrosomal deficiency and nuclear abnormality resulting in dumbbell-like appearance
C. Acrosomal deficiency, kinked midpiece, tail mainpiece and endpiece abnormality
D. Enlargement of the acrosome and nuclear abnormality resulting in a round appearance

Cellular Constituents of Semen

White blood cells, red blood cells, epithelial cells, and spermatogenic cells are seen during routine semen analysis. It is important to identify polymorphonuclear white blood cells since they may indicate an infection of the male reproductive tract that requires antibiotic treatment. Red blood cells may also be seen due to trauma or infection. Epithelial cells from the urethral canal are present in normal semen.
Spermatogenic cells and spermatids are germ cells that are sloughed off early in the maturation process. An occasional immature cell is found in normal semen, but an excessive number can denote maturation arrest. Maturation arrest can be idiopathic or the result of a varicocele, mumps orchitis, exposure to toxic substances, or sickle cell disease. \(^{1(p28)}\) Accurate differentiation of the cellular constituents is important for proper treatment. Polymorphonuclear white blood cells are identified by their regular size and shape, consistent nuclear/cytoplasmic ratio, and interconnected nuclei. Red blood cells and epithelial cells are easily recognized by their distinctive size and shape. Spermatogenic cells, on the other hand, are not regular in size or shape and have a varying nuclear/cytoplasmic ratio depending on their stage of maturation. Bodies within the cell are not interconnected. An entire cell can appear like a mass of cytoplasm with sprouting tails. As a spermatid matures in the epididymis, it loses its surrounding cytoplasmic mass. A sperm with a cytoplasmic droplet greater than 1/3 the size of the sperm head is considered abnormal, denoting immaturity. The cytoplasmic droplet also known as a cytoplasmic extrusion mass is generally seen in the area of the neck and midpiece, but occasionally it will be seen surrounding the entire sperm head or be entangled in the coiled tail of sperm with tail abnormalities.

Cellular constituents are seen in Figure 8:

Figure 8:

A. Normal polymorphonuclear white blood cell
B. Normal red blood cell
C. Normal epithelial cell
D. Spermatid
E. Spermatids engulfed in cytoplasm
F. Sperm with abnormally large cytoplasmic droplet
G. Spermatogenic cells
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References


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