Choosing Surgical Lighting*

University of Tennessee
Jean E. Loonam, DVM
Darryl L. Millis, MS, DVM, DACVS

ABSTRACT: If you are contemplating building a new practice or remodeling an existing one, it will become apparent that few or minimal reference materials are available to aid in choosing surgical lights. A literature search reveals only one paper, published in 1980, about veterinary surgical lights. More reports on surgical lighting have appeared in the human medical literature, but most of these were published in the 1970s and 1980s. This paper aims to help veterinary practitioners understand the various factors and terminology associated with lighting to aid in the evaluation of the many different brands and types of surgical lights.

One of the most difficult decisions in building a new veterinary hospital or redesigning an existing one is the provision of surgical lighting. The terms used to describe characteristics of surgical lights and the vast choices of lighting options available are generally not common knowledge to most veterinarians. Moreover, the purchase of surgical lights can be a very expensive and crucial decision, with the cost to outfit a single operating room ranging from $3,000 to $50,000.

Several factors must be considered before deciding which lights to purchase: brightness (light intensity); color correctness; heat production; shadow reduction; depth of field and focus; ease of changing and reliability of bulbs; maneuverability and drift; and cost (Table 1). Veterinarians should be familiar with the technical terms and standards used to describe surgical lighting so that they can make an informed decision when purchasing surgical lights.

BRIGHTNESS

Illumination is the amount of light delivered by a source to a specific area. It is measured in foot-candles (North America) or in lux (Europe). To understand the relationship between foot-candles (ft-c) and lux, consider a standard point source of light of one candela (candle) at the center of a sphere 1 ft or 1 m in radius. The illumination at any point on the sphere is 1 ft-c (1 lumen/sq ft) when the radius is 1 ft, or 1 lux (1 lumen/m²) when the radius is 1 m. One foot-candle is equal to approximately 10.8 lux. The Illuminating Engineering Society of North America (IES), which provides standardized terminology regarding lighting, recommends a minimum of 2,500 ft-c of illumination when a light is positioned 1 m above the surgical site. Most surgeons actually prefer up to 3,500 ft-c. Surgical lighting today can easily approach 10,000 ft-c of intensity.

*Dr. Loonam is currently affiliated with the Clay-Duval Pet Emergency Clinic, Orange Park, FL.
which is equivalent to bright noonday sun. This is not ideal in a surgical situation because most people require dark sunglasses in such intense light.

Lighting needs for the entire surgical suite should be divided into at least two groups and possibly three. General lighting is the lighting provided for the entire room. The IES recommends approximately 200 ft-c for this area. Task lighting refers to the light available for a specific task, in this case the surgical field, which should be approximately 2,500 ft-c for surgeries. Some also consider the light that is available outside of the task lighting, which in this case is the light around the edge of the surgical field. The recommended illumination for this area, called the surrounding zone, is 300 ft-c. The brightness ratio is the ratio of task lighting to general lighting. Brightness ratio is important because it affects visual performance. If a great difference in light intensity exists between the visual task area and the general area, the eye must constantly adjust, and fatigue will result. Research has shown that a brightness ratio of 3:1 or lower between the task and general lighting will not result in fatigue. Based on the common preferences of surgeons for task lighting at around 3,500 ft-c, the general lighting of the surgical suite would be around 1,200 ft-c. This differs from the IES recommendation; therefore, each surgeon should try several different levels to determine what is most comfortable. Different brightness ratios may be more appropriate for different types of surgeries, such as for arthroscopic procedures versus abdominal exploration.

Another problem to consider is glare. Glare is defined as discomfort or reduced seeing ability when light reaches the eye that is more intense than the light to which the eye is adapted. The type of glare may be direct, such as from looking straight into a surgical light, or reflected from surgical equipment. Although high-intensity light must be used because of the low reflectance of light from tissues and blood, the high intensity may cause severe glare when light is reflected from highly polished instruments or white drapes and materials. This type of glare may be reduced with satin-finish instruments and the use of drapes and gowns made of blue and green material.

### COLOR CORRECTNESS

Color quality is the measure of spectral content of light expressed in degrees Kelvin (°K) (Figure 1). Consider the color spectrum known by the mnemonic

| Table 1. Factors to Consider When Assessing Surgical Lights |
| --- | --- | --- |
| Item | Unit | Recommendation |
| Intensity | ft-c | 2,500–4,000 ft-c |
| | lux | 25,000–40,000 lux |
| Color correctness | °K | 4,000°K–5,000°K |
| | Color-rendering index | >90 |
| Heat production | mW | <25 mW |
| Total weight | lb | Structural soundness of installation site must be adequate to support chosen light |
| Maneuverability | lb | 2–5 lb |

![Figure 1—Spectral content of light. Degrees Kelvin are indicated at various positions along the spectrum, along with natural and artificial light sources.](www.VetLearn.com)
ROYGBIV (red, orange, yellow, green, blue, indigo, and violet). The majority of surgeons prefer lights that fall somewhere between 4,000˚K and 5,000˚K, which is in the pale yellow to white to pale blue range of the spectrum. Most surgical lights today use halogen bulbs, which typically fall in the range of 2,900˚K to 3,000˚K. Special filters are used to change the color to fall in the 4,000˚K to 5,000˚K range. The color of this light is similar to noon light on a cloudless day. This color quality range is important because changes in the color of the light will change the perceived colors of tissue. For instance, very blue or yellow light decreases the ability to see cyanosis, tissue perfusion, jaundice, and color variations within an organ. As related to the temperature scale, low-color temperatures (<3,000˚K) cause objects to have a reddish tint, whereas high-color temperatures (>8,000˚K) produce a bluish tint. Light intensity and reflections from other objects around the surgical field will also affect the perception of colors.

Color correctness is also sometimes evaluated using the color-rendering index (CRI), which is the effect that a light source has on the appearance of an object’s color. CRI is evaluated on a scale of 1 to 100, with outdoor light having a CRI of 100. In general, the higher the CRI, the better the color-rendering properties of a lamp. CRI is used in combination with degrees Kelvin to evaluate light sources.

HEAT PRODUCTION

Light can produce heat in two ways. The first is by producing invisible infrared rays. The other is by energy transformation of the illuminated object, or heat that is generated when light strikes an object. This is called radiant energy. Infrared rays are removed by heat-absorbing filters or dichroic reflectors (cold mirrors), which dissipate the heat away from the field and either out the back or to the side of the light. There have been recent advances in the area of heat dissipation with regard to laminar airflow patterns so that the flow of air is not into the surgical field, which may help prevent infections.

The IES has determined that the radiant energy at the level of the surgical site cannot exceed 25 mW/cm². A way to test this level is by the black spot test. In this test, a 1-cm black spot is painted on the back of the wrist using India ink or a felt pen. This spot is held at the light beam’s brightest point (i.e., focal point) for 1 to 2 minutes. If the radiant energy is 25 mW or less, the skin temperature will be raised by only 2°C. If the radiant energy is any higher than 25 mW, the area will become painful if heat production is excessive. This is important when performing surgery on delicate tissues such as bowel. Most veterinarians are aware that anesthetized patients may suffer burns from heating pads. However, burns may also result from surgical lights that either malfunction or have had important components, such as the heat filters, removed or broken. There have been case reports of humans who suffered burns from malfunctioning surgical lights. One patient undergoing prostate surgery was burned after a broken heat filter was removed but not replaced. He developed a 5 × 12-cm full-thickness burn to his abdomen. In another case report, three women undergoing facelifts developed...
large burns on their faces as a result of a faulty heat-filtering device.³

**SHADOW REDUCTION**

In the early 1920s, most operating rooms were built on the top floor of hospitals. Large bank-type windows and skylights provided lighting for surgeries, which were often performed around noon when sunlight was brightest. In 1920, Professor Verain developed a scialytic lamp, on which all other surgical lights are based.⁰ The idea was to design a light that would not be blocked by the surgical team and thus would reduce shadow formation. Shadows have two aspects (Figure 2). The first is the *umbra*, or area of absolute shadow where all light is blocked. The other is the *penumbra*, which is the area of partial shadow around the edges of an image or object.¹¹

All modern light designs try to eliminate shadows by directing light as a hollow cone around the surgeon’s head. This is accomplished typically in one of three ways. The first method is to have a single bulb surrounded by large parabolic reflectors. The second method is to place several bulbs in a hemispheric unit, with each bulb focused on a certain apex of the hollow cone. The third method is a combination of the first two, where multiple small bulbs with parabolic reflectors are placed in a hemispheric shape so that the sum of the small cones creates a larger hollow cone.¹⁹ Complete shadow reduction is actually undesirable. If the shadows that arise from the contours of the surgical field were completely eliminated, the surgeon would lose depth perception.⁶

**DEPTH OF FIELD AND FOCUS**

The light beam must not only go around the surgeon’s head and hands but must also give adequate illumination to surgical sites that are often in deep cavities. The *focal point* is where illumination from the surgical light fixture converges and is brightest. This focal point will remain essentially constant. With most surgeries a single focal point is not ideal, however, because the positioning of tissues of interest may change. Most lights are now developed to have an area of focused depth rather than a single focal point (Figure 3), which requires less adjustment of lights by the surgeon during the procedure. Multiple-bulb light fixtures allow for a greater depth of field compared with a single-bulb lamp. There are two ways to maximize illumination and depth of field in deep areas, such as the abdomen. One is to have the centerline of a single light beam angled from the right ear to the right index finger for right-handed surgeons.⁷ Another method is to project two beams of light from both the right and left of the surgeon.⁵ Although two surgical lights are more expensive than a single light, there are advantages to using multiple lamps and multiple-bulb lamps because the depth of field and illumination in deep body cavities are improved.

**CHANGING AND RELIABILITY OF BULBS**

Most bulbs used in surgical lights today are halogen bulbs, although incandescent or xenon bulbs are also used occasionally. Halogen bulbs typically last at least 1,000 hours, or about 25 weeks, if the lights are used 8 hours a day, 5 days a week.⁷ The fear, especially with a single-bulb lamp, is that a bulb will go out during a procedure. Most lamps, especially multiple-bulb lamps, have
a backup bulb that automatically lights if the other bulb is lost. Failure of a halogen bulb will most likely occur when turning the light on, not during the procedure. Inserting a new bulb can be difficult if the light has been on for some time and is hot. Caution must be used when replacing bulbs because dirt or fingerprints on halogen bulbs can cause premature failure or discoloration. To prevent this, the manufacturer usually packages the bulb to prevent direct contact while it is being replaced. Manufacturers usually recommend a specific bulb to use in their lights; this may increase the life of the bulb as well as the output and quality of the surgical light.

**MANEUVERABILITY AND DRIFT**

Many modern surgical lights are rather large and can be very heavy. The ease of positioning can be assessed by the number of pounds of force needed to move the light. A minimal amount of force to move the surgical lights is desirable to reduce fatigue and physical stress on the surgical team. Typically, a well-designed light requires 2 to 5 lb of force to be positioned. However, when lights are designed to move more easily, the chance of drift increases. *Drift*, or the change in a light’s position after the light is set in place, can be very frustrating and time-consuming. Some reports have shown that human surgeons spend up to 25% of their surgical time adjusting and positioning lights. Some lights have magnetic locks that help eliminate drift. Both maneuverability and drift are affected by the light’s degree of levelness following installation. It has been our experience that higher-quality lights have less drift and require less maintenance to reduce drift than do lower-quality lights.

Most lights should be suspended from the ceiling to provide clear floor space. Mounting of surgical lights and the required support systems should be discussed with an architect. Good-quality surgical lights can weigh 150 to 1,000 lb, depending on additional equipment installed along with the light. Most large, institutional-size lights require additional ceiling supports because of their size and weight. The lights should be properly mounted and counterbalanced so that they are easy to move and drift is reduced. Each light should be equipped with a large, nonsterile handle so that a nonsterile assistant can position it as well as a handle that can be sterilized or has a sterile cover so that the surgeon can fine-tune the position.

**COST**

Investing in good-quality surgical lighting is an expensive venture. In this area of equipment planning, buying cheaper lights may be more costly in the long run because of the need for upgrades or new bulbs. Referral hospitals and teaching institutions may spend $10,000 to $30,000 on lighting for a single surgical suite. Often, video equipment as well as closed-circuit television may be included in the lighting fixture. General practitioners can typically purchase a single light for about $3,000. Single spotlights can then be added for about $2,000. As discussed earlier, personal preference determines whether a single lamp with several spotlights or two lamps are most desirable. It is probably best to budget a minimum of $7,000 to $10,000 for surgical lights in a suite, depending on what types of surgeries are performed and the preferred light intensity. Used lights may also be purchased from surgical supply companies. Make sure that warranties exist on these lights and that replacement parts can be purchased easily. Used lights may allow a substantial decrease in price, but this may be at the cost of service.

**CONCLUSION**

Purchasing surgical lights can be a daunting task. Many options and variables must be considered when choosing surgical lights. For example, some surgeons prefer to perform surgery with a headlamp. The drawbacks of using such a light source are similar to those of the...

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**Manufacturers of Surgical Lights**

- **ALM Surgical Equipment**
  1820 North Lemon St.
  Anaheim, CA 92801
  714-578-1234; 800-842-2555

- **Berchtold**
  1950 Hanahan Rd.
  PO Box 60399
  Charleston, SC 29419-0399
  843-569-6100; 800-243-5135
  [www.berchtoldusa.com](http://www.berchtoldusa.com)

- **Medical Illumination International**
  547 Library St.
  San Fernando, CA 91340
  818-838-3025; 800-831-1222
  [www.medillum.com](http://www.medillum.com)

- **Skytron**
  5000 36th St. SE
  Grand Rapids, MI 49512
  616-957-0500; 800-759-8766
  [www.skytron.us/index.htm](http://www.skytron.us/index.htm)

- **Steris**
  5960 Heisley Rd.
  Mentor, OH 44060-1834
  446-354-2600; 800-548-4873
  [www.steris.com](http://www.steris.com)
using a single lamp. Surgical lights can also vary greatly, particularly in specialty practices where other instruments such as arthroscopes or fluoroscopes may be used. Appropriate ambient light sources need to be adjusted so that the user of the additional equipment is comfortable with visualization. It is always important to get the opinions of colleagues regarding their experience with surgical lights in practice. Surgical light distributors can provide the names of facilities where their lights have been installed. Veterinarians who are working with an architect can find out what lights were used in other designs and whether the customers were satisfied. This list, although far from exhaustive, will at least provide a starting point for evaluating types of surgical lights that will work best in individual hospitals.

REFERENCES


1. Illumination, or the amount of light delivered by a source to a specific area, is measured in
   a. lux. c. lumens.
   b. foot-candles. d. a and b

2. Discomfort or a reduced ability to see when a light reaches the eye that is greater than the light to which the eye is adapted is known as
   a. penumbra. c. depth of field.
   b. glare. d. focal point.

3. Most surgeons prefer light that falls within which color quality range?
   a. 2,900˚K to 3,000˚K c. 4,000˚K to 5,000˚K
   b. 8,000˚K to 10,000˚K d. 7,000˚K to 8,000˚K

4. The IES has determined that the radiant energy at the level of the surgical site cannot exceed ____ mW/cm².
   a. 20 c. 2
   b. 2.5 d. 25

5. Which of the following statements regarding shadow reduction is true?
   a. In the early 1900s, shadow reduction was achieved by performing surgery early in the morning.
   b. There is only one method of designing lights to reduce shadow formation.
   c. Complete shadow reduction is undesirable because it causes a surgeon to lose depth perception.
   d. Modern lights eliminate shadows by directing the lights as a hollow cone around the surgeon’s hands.

6. Which of the following lighting methods will achieve the greatest depth of field?
   a. multiple-bulb light fixtures
   b. angling a single light beam from the right ear to the right index finger for a right-handed surgeon
   c. two beams of light projecting from both the right and left of the surgeon
   d. all of the above

7. Halogen bulbs typically last for ____ hours.
   a. 10,000 c. 2,000
   b. 1,000 d. 3,000

8. How many pounds of force are required to position a well-designed light?
   a. 1 to 2 c. 2 to 5
   b. 6 to 9 d. 5 to 8

9. In which way can surgical lights cause burns to patients?
   a. excess radiant energy
   b. excessive umbra
   c. malfunctioning heat filters
   d. a and c

10. What is the CRI?
   a. effect that a light source has on the appearance of an object’s color
   b. measure of spectral content of light
   c. light available for a specific task
   d. amount of light delivered by a source to a specific area