

Advancements in Surgical Lighting Systems and Their Clinical Implications



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Advancements in Surgical Lighting Systems and Their Clinical Implications

Study Guide #16

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Description of study guide topic

Throughout the years, advancements in surgical lighting have enhanced the surgical team's ability to illuminate the surgical site. In particular, these improvements have included the ability to control light positioning, illumination intensity, pattern size and other features. No longer are surgical lights simply on or off. Today's advanced systems offer many features that require an understanding of lighting technology, along with measures to ensure safe operation. This study guide will provide an overview of surgical lighting terms while describing practices needed to ensure patient and surgical team safety.

The study guide is intended as a companion to Study Guide #3, *Lighting the Way to Surgery: What is Needed in a Surgical Light*, which covers the basics of surgical lighting. This study guide goes into more depth on some of these basic topics and emphasizes new developments in surgical lighting and particularly their clinical implications for safe and effective use.

Overall purpose of the study guide

To explore today's surgical lighting technology and practices needed to ensure safety.

Objectives

Upon completion of this study guide program, the participant should be able to:

1. Define terms that characterize illumination and surgical lighting technology.
2. Review safety measures needed when using today's overhead surgical lights.

Intended audience

This study guide is a self-study program intended for use by perioperative nurses, surgical technologists, perianesthesia nurses and staff members, endoscopy suite nurses and staff members, acute care personnel, physician office and clinic personnel, surgeons and other healthcare professionals interested in this topic.

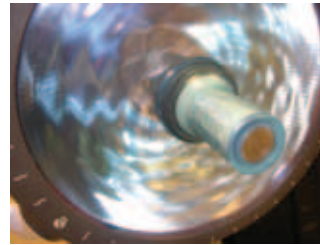
ADVANCEMENTS IN SURGICAL LIGHTING

Since the early days of surgical practice, there have been continuous advancements in surgical lighting systems. Some of these changes have been relatively minor, while others have provided dramatic improvements and significant progress towards optimal lighting. From the first clusters of incandescent lights that were suspended over a patient in the early 1900s, the purpose of surgical lighting has been to precisely illuminate the operative site. In the beginning, surgical lighting was relatively simple. The surgical team turned the lights on, aimed the beam at the target and focused the spot on the operative site. Attention was directed toward surgical technique, surgical tools and patient monitoring. Even though surgical lights were simple and dependable, surgical lighting still presented a challenge with many unmet needs. As surgical lighting technology evolves and matures, these unmet needs are being addressed because of the importance of the work performed using surgical lights.

Over the past decade, intense research has led to product advancements that have introduced a new era for surgical lighting systems. Advancements in lighting technology and surgical procedures have driven these needed changes in surgical lighting systems. Controls and adjustment options now allow the surgical team to fine-tune the lighting for ultimate visualization during the surgical procedure. As with any new equipment that promotes choices and alternatives, this new technology must be understood so that safe practices can be employed.

LIGHT SOURCES FOR SURGICAL LIGHTING

One of the most obvious and fundamental changes in surgical lighting is the way in which the light is created. The advent of LED light sources has revolutionized the lighting industry and surgical lighting market in particular. Although the vast majority of OR lights currently in use throughout the world are incandescent, most areas of the world are seeing rapid growth in the sale of LED-based surgical lights and, in fact, most new sales in the leading hospitals in North America are for surgical lighting systems that use LED light sources. A review of the features and benefits of various light sources will explain why this trend is occurring.



Halogen Lamps

A halogen lamp is an improvement to the basic incandescent lamp that produces light by passing a current through a tungsten wire so that the wire gets hot enough to radiate visible light. In a halogen lamp, the tungsten filament is sealed into a compact transparent glass envelope filled with an inert

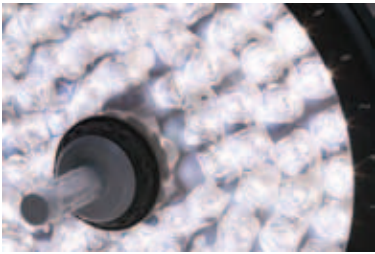
gas that contains a small amount of additives from the halogen family of elements, such as bromine. The halogen additives allow the filament to operate at a higher temperature than a standard gas filled lamp of similar power without loss of operating life. The halogen lamp also typically produces light of a higher color temperature compared to a non-halogen lamp. Halogen lamps get hotter than regular incandescent lamps because the heat is concentrated on a smaller envelope surface and because the surface is closer to the filament. There are many names for incandescent lamps that emphasize different aspects of their design, such as glass halogen, quartz halogen, tungsten halogen, and xenon halogen, but they are all minor variations of standard incandescent technology.

Gas Discharge Lamps

Gas discharge lamps are a family of light sources that generate light by passing a current through ionized gas, thus producing an electrical discharge, or arc. Gas discharge lamps offer longer life than halogen bulbs and higher light efficiency, but are more complicated to manufacture and operate. They require sophisticated electronics to provide the correct electrical characteristics to start the lamp and then stabilize its operation. Three serious deficiencies in gas discharge technology are 1) that it is difficult to restart a lamp immediately after it has been turned off, 2) lamps may require many minutes to reach full operating intensity and stable color, and 3) it is difficult to dim the lights without causing a shift in the apparent color of the light. Although there are ways to overcome each of these challenges, they come with a price in terms of complexity, cost and reliability. For example, some surgical lighting manufacturers have chosen to use a different type of light source, typically a quartz halogen lamp, as a secondary source to provide immediate backup when the primary light source fails. These back-up lamps may not provide the same intensity level as the initial discharge lamp, thus providing reduced performance when the back-up is on.

Light Emitting Diode (LED)

The newest surgical lights use Light Emitting Diode (LED) technology, which emits light by passing a current through a solid semiconductor material. Light is emitted through an entirely different mechanism than incandescence so the components of the LED stay relatively cool. Obvious advantages of LEDs include longer life and the possibility of higher energy efficiency. A less obvious, but significant, additional benefit is that LEDs radiate much less heat than incandescent bulbs, so that less heat is delivered to the surgical site, reducing the risk of drying out exposed tissue. Cooler lights also mean that the surgeon and staff are more comfortable, which is important during long cases.



Another notable feature of high quality LED surgical lights is how white the beam appears. Traditional halogen bulbs are inherently yellow, with typical color temperatures around 3200 Kelvin (K). Manufacturers attempt to correct this yellowness by using

expensive coatings and filters to remove some of the yellow light, which raises the color temperature to a more desirable level (around 4400K). This filtering makes the light whiter but the color is still less than ideal. Also, the coatings and filters are very difficult to apply consistently, so manufacturing costs and lighthouse-to-lighthouse color variability are high.

Not only are LED lighthouses whiter and more consistent, they provide surgical lighting designers with much greater flexibility, since lighthouses typically use a large number of small LED sources, rather than a single high intensity light source and a single large reflector. This allows LED surgical lights to be much thinner and streamlined, while still providing excellent shadow control and uniformity of light within the beam. In a typical LED lighthouse, each LED produces the entire spot. These individual spots are then precisely overlapped, so no matter how many LEDs may be blocked by obstructions, the spot remains round and consistent. As obstructions (e.g. surgeons' heads) move around in the light field, the pattern does not change, which means that surgeons won't be distracted by shadows moving across the pattern.

Lamp Life

The practice of replacing burned out lamps in surgical lights has been a routine part of life in the OR for as long as artificial lighting has been used in surgery. However, the advent of LED light sources in surgical lights is making lamp replacement a thing of the past. Not only do LEDs last as much as 40X longer, the way in which they ultimately fail is entirely different. This leads to an alternative understanding of what is meant by the life of a light source.



Incandescent lamps will fail when their filaments evaporate to such a degree that they break apart and can no longer conduct current. This familiar mode of failure results in the light completely going out in an instant. Since this can obviously have catastrophic consequences during a surgical procedure, surgical lighting manufacturers have designed systems to detect the failure of the primary light source and switch power to a back-up

light source that is located within the lighthouse. Less expensive designs turn on a stationary back-up lamp that is located as close as possible to the primary lamp, which restores the light output but may distort the pattern size, shape and intensity, since the back-up lamp is not in the optimal location within the lighthouse. A more costly, but better performing, alternative is after detecting the failure of the primary lamp, to immediately move the primary lamp out of the way and position a back-up lamp into the optimal location and restore the light output completely without any compromise in performance. It is important that the back-up lamp be in working order prior to starting a surgical procedure, so that it will be available when needed. A good system design will inform the user if the back-up lamp is missing or has burnt out. This may be accomplished with an indicator light on the lighthouse or a light or message on the light controller.

If a lamp begins to flicker, it should be replaced promptly. A burnt out lamp in a multilamp fixture should also be replaced quickly, since it may cause an increase in the voltage to the remaining lamps and thereby reduce their lifetime. The manufacturer's written instructions should be followed when replacing a lamp. A lamp should never be replaced nor should a lighthouse ever be cleaned unless the lighthouse is turned off and it has cooled sufficiently. The glass envelope of the lamp should not be touched with bare skin since fingerprints can result in deterioration and discoloration, thus reducing the lamp output. A clean cloth should be used to handle lamps, and proper disposal methods for the lamps must be followed. If the lamp envelope contains high pressure gas, then explosion warnings must be followed. Eye protection should be used when working with these lamps.

Incandescent lamps last around 1000 hours of typical usage, but there is a large variability from lamp to lamp, even under nearly identical conditions. Lamp life for an incandescent lamp is defined as the median life for a representative sample, that is, the time at which half of the lamps being tested have burnt out. Lamp life is heavily dependent on the intensity setting, so that frequently operating the lights at the highest intensity setting can reduce lifetimes to much less than the rated life. However, as long as the lamp is still operational, the light output remains fairly consistent.

LED light sources are entirely different from incandescent lamps in terms of life. An LED will not typically burn out in an instant, but rather the light output will gradually decline, continually, during the lifetime of the light. The life of an LED is defined as the time at which the light output has dropped to a certain percentage of its initial value. The lighting industry has adopted the standard of a 30% drop in light output as the end of life condition. Since LEDs operate at temperatures so much lower than incandescent filaments, there is no cause for an instantaneous failure like an incandescent lamp would have, although there is a slow degradation in the materials which gradually reduces the light output. Typical LED-based surgical lights have rated lifetimes from 20,000 to 40,000 hours. At the upper end of this range, LEDs will last for more than 10 years in typical usage and can be considered to last for the practical lifetime of the lighting system, so that LED replacement is not required. With lifetimes this long, other electrical components in the system may be as likely to fail as the LEDs themselves, so the predicted lifetime of the entire system should be considered, not just the LED lifetimes. LED life depends on the operating temperature of the LED which depends on how effectively the LEDs are cooled. LEDs may also exhibit a slight change over time in the apparent color of the white light they emit, but this change is also very gradual and not generally noticeable.

SURGICAL LIGHTING SAFETY

For years, surgical lighting systems have been extremely safe. While new lighting technology in the latest surgical lighting products has improved the inherent safety of surgical lights even further, surgical team members may not be aware that some of the recent trends in product performance may lead to unsafe practices.

Light and Heat

One of the most obvious trends has been the gradual increase in light output provided by a single luminaire during the last few decades. During the 1960s, 70s and 80s, the peak illuminance of most surgical lights was in the range of 80,000 to 110,000 lux. In the 1990's, the illuminance rose to 100,000 to 130,000 lux. Today, the peak illuminance ranges from 100,000 to 160,000 lux, with many of the premium products above 140,000 lux. This means that today's surgical lights are typically more than 1.5 times brighter than those in use just a few decades ago, which is a significant increase. In fact, many of today's leading surgical lighting systems now deliver illuminance levels that are at or near the upper regulatory limit of 160,000 lux for a single lighthouse established in IEC 60601-2-41, "Particular requirements

for basic safety and essential performance of surgical luminaires and luminaires for diagnosis.”¹

While the increased illuminance can be helpful for visualizing the surgical site, it is important to realize that increased illuminance delivers additional radiant energy to the surgical site which may be absorbed and lead to elevated tissue temperature and possibly damage due to thermal burns. The same radiation that produces a visible sensation when it strikes our retina produces heat when it is absorbed by our body and heat increases tissue temperature. However, radiation in wavelengths that are not visible may also produce heat. In fact, infrared (IR) radiation, which is not visible, is readily absorbed by the body and may be a significant contributor to the perception of the amount of heat in the beam from a surgical light. Ultraviolet (UV) radiation is also not visible, but may also damage tissue, although the mechanism is different (photochemical rather than thermal) than IR radiation.

The amount of radiant energy, at different wavelengths, that reaches the surgical site depends on how much radiant energy is emitted by the light source, how the optical components of the surgical luminaire collect and focus the light on the surgical site, and the degree to which non-visible wavelengths, such as infrared and ultraviolet radiation, are filtered out of the beam. Well-designed surgical lights will minimize the emission of radiant energy in the infrared and ultraviolet region so that the remaining energy is almost entirely in the visible region. Since incandescent light sources emit a large portion of their energy in the infrared, sophisticated reflector coatings and heat filters have been designed to minimize the amount of heat delivered to the surgical site, which is extremely important if brighter light is desired. These methods can be used singly or in combination to direct the visible wavelengths to the surgical site while allowing the infrared (heat-producing) waves to stay away from the patient. Some surgical lights dissipate about 98% of the heat produced out of the back of the lighthouse and away from the surgical field.

Heat and Risk of Thermal Damage to Patients

The most obvious side effect of radiant energy is to raise the temperature of the surface that it strikes which can lead to drying or ulceration of exposed tissue and even in rare cases to thermal burns of delicate tissue. However, there are many factors in addition to the amount of radiant energy reaching the surface that control how quickly and how high a person's tissue temperature will rise. A person's ability to withstand a certain level of radiant energy depends on intrinsic factors such as their age, skin pigmentation, overall health of their skin and circulatory system and the effects of any medication they may have taken recently. There are also extrinsic factors, that is, factors outside of the patient, which determine how a specific heat load will raise the patient's tissue temperature. For instance, irrigating the surgical site can dramatically reduce the risk of tissue damage from excess heat, while increasing the length of exposure to the intense light can increase the risk.

The risk of thermal damage due to radiant energy is greater for certain procedures, such as neurosurgery and surgery on thin, hyperemic (excessively swollen) tissues such as distended intestines. Pediatric patients and those with compromised circulation may also be at increased risk. Nursing considerations must include an assessment of the patient's potential photosensitive responses as determined by age, disease state, medications, locations of surgery and the durations of the procedure. Some of the factors to consider include:

- > Age of the patient – the older the patient, the more photosensitive he or she may be
- > Disease state – diabetes, radiation therapy, auto-immune disorders may cause more sensitivity to lighting

- > Location of surgery – tissue type; for example, certain neurological procedures and intestinal procedures may expose delicate tissue to the drying effects of surgical lighting
- > Length of surgery – with a longer duration of exposure to intense lighting, tissue can be adversely affected
- > Medications – antibiotics, sulfonamides, tolbutamide, NSAIDs, anti-cancer drugs, estrogens, certain diuretics, thiazides, cyclamates and others may cause increased sensitivity to surgical lighting
- > Topical treatments may cause increased sensitivity to surgical lighting

The risk of thermal burns is not only due to the overhead lights. Patient burns during surgery have been reportedly caused by a variety of different light sources including microscope lights and fiberoptic lights, as well as overhead lighting systems. Surgical team members realize that the intensity of a microscope light that is focused on an operative area can lead to tissue dryness and destruction. Maximum light intensity should only be used with caution and for the shortest duration possible. Surgical team members should also understand the need to readjust the positioning of a microscope light and to use sterile wet gauzes and/or irrigation to keep the surgical site moist and cool. A fiberoptic light cable must be attached to an endoscope before turning the light source on as the heat generated near the tip of a disconnected fiberoptic light cable can easily ignite combustibles.

However, surgical team members may not be as aware of the problems that can be caused by tightly focused overhead lights using today's powerful surgical lighting systems. An actual case report noted that three patients, each having a rhytidoplasty procedure in an office-based surgical facility, sustained third-degree burns on their left cheeks. Dual ceiling-mounted lights were used that were focused in an overlapping manner on the surgical site. The burns were determined to be the result of the combination of a specific defective light fixture and bulb. Since epinephrine had been injected, vasoconstriction of the vessels while the tissue was being undermined added to the risk of thermal damage to the exposed tissue. Aiming both lights on the surgical area had also increased the amount of radiant energy delivered to the site.

Both the Illuminating Engineering Society of North America (IESNA) and the International Electrotechnical Commission (IEC) have addressed the need to draw special attention to the risk of thermal damage to patients due to surgical lighting. The Recommended Practice for Lighting for Hospitals and Health Care Facilities developed by the IESNA states:

“Radiant heat produced by surgical lights must be minimized to protect exposed tissues and provide comfort to the surgical team.... Excessive heat from the lighting quickly dries tissue, requiring more frequent irrigation.”²

The IEC standard for the basic safety and essential performance of surgical luminaires and luminaires for diagnosis specifies that the total irradiance in the lighted area from a single lighthouse shall not exceed 1,000 W/m^{2,3}. Many modern surgical lights produce only about half of that amount, even on their highest intensity setting and smallest pattern size, which is their highest irradiance condition. However, when the beam patterns of two or more lights are overlapped, the surgical staff must consider the increased risk of overheating the exposed tissue and may need to limit the intensity of the light, limit the exposure time or take other means to reduce the risk to the patient. The IEC standard addresses this specific risk by stating:

“If it is possible, in the case of surgical luminaire systems, to exceed an irradiance of 1,000 W/m² by overlapping the light fields of several lightheads, information shall be given in the instructions for use that there is a risk of too much heat in the operating field.”⁴

An example of compliance to this requirement is provided in the advisory from STERIS Corporation in the Operator’s Manual for their Harmony LED Surgical Lighting System, which states:

“As illumination levels increase, however, radiant heat should be kept to a minimum. The user of surgical lights should utilize the lowest possible illumination level suitable for the procedure, especially in certain neurological or intestinal procedures on delicate, thin, dry or abnormal tissue. Furthermore, for the protection of surgically exposed tissues and for the comfort and efficiency of the surgeon and assistants, radiant energy can be effectively controlled by limiting the time of exposure at higher illumination levels. Extra care must be taken when the light fields from multiple lightheads are overlapped on the surgical site, since this condition creates a risk of too much heat.”⁵

Keep in mind that advancements in surgical lighting technology have expanded the responsibilities of the surgical team. Some of the practices that the surgical team can use to reduce the risk of thermal damage include:

- > Starting the procedure with a low or medium light intensity setting and increasing the intensity of illumination only as needed during the case, thus using the lowest possible intensity setting with the minimal radiant heat without sacrificing visibility of the surgical site.
- > Using drapes or other coverings to decrease the amount of light exposure on the tissue, especially when using higher intensity settings or during long procedures.
- > Decreasing the intensity and duration of exposure to the light, especially when overlapping light fields.
- > Keeping tissue moist and cool when possible using irrigation and wet sterile sponges.

It may seem intuitive that adjusting the lighthead to reduce the pattern size will reduce the amount of radiant energy reaching the surgical site, but in fact, this approach may actually increase the risk of localized thermal burns. Many surgical lights reduce the pattern size by more tightly focusing the available light, rather than reducing the total amount of light and heat. A smaller pattern size will typically have higher illuminance and higher irradiance than a larger pattern at the same intensity setting.

Heat and Surgical Team Comfort

While patient safety is of utmost importance, radiant heating from surgical lights can also play a role in the comfort of the surgical team. At times, the beam of light from the surgical lights may strike the heads and shoulders of the surgical staff during the procedure. While this will not cause any harm to the surgical staff, over time it may cause the staff to feel some warmth due to the lights. So a surgical light that produces a minimal amount of infrared radiation will be appreciated by the staff, as well as minimizing the risk of harm to the patient.

Heat and Lighthead Performance and Reliability

While excess radiant heat can increase the risk of thermal damage to patients and cause discomfort for the surgical staff, excess heat within the surgical lighthead will adversely affect the performance and reliability of the equipment itself. Excess heat can cause a decrease in light output, reduced LED lifetimes and over a period of time can

cause electrical insulation to melt, crack, or dry. Surgical lightheads are specifically designed to move the heat away from the LEDs and transfer it to the large back cover of the lighthead where it can be slowly dissipated to the room. This causes the back covers of surgical lightheads to become quite warm to the touch, especially after the lights have been on for awhile. Manufacturers must ensure that surface temperatures are safe to touch, especially in those areas that are designed to be grasped for aiming, positioning and controlling the lights.

SURGICAL LIGHTING PERFORMANCE

Color

Surgical lighting has always used white light, from the early days of performing surgery under daylight to the use of artificial incandescent light. These light sources provide a broad distribution of wavelengths throughout the visible spectrum. Filters and coatings applied to reflectors and lenses have provided some limited and typically expensive means of controlling the appearance of the light. The recent advent of LED lighting technology requires a much greater awareness of the subtle differences in white light, as LED technology is capable of more precise control of how the radiant energy is distributed across the visible spectrum. The two main measures used to describe the apparent color of the light and its ability to render various colors are the color temperature and the color rendering index, respectively. These metrics have become much more important factors in evaluating and comparing LED-based surgical lights, since LED technology provides users with a much greater range of performance.

The color temperature, or more precisely, the Correlated Color Temperature (CCT), of a light source is measured in Kelvin (K) and describes the apparent color of light. It is only used to describe various shades of white light, not colored light. Light with a color temperature in the range of 2700 – 3400K appears white but with a relatively red / yellow hue and is often referred to as “warm white.” This is typical of an unfiltered incandescent lamp. Light with a higher color temperature in the range of 4100 – 6300K appears white with a blue hue and is often referred to as “cool white.” Surgical lights typically have a color temperature around 4400K which many find to be a pure, neutral white light that is neither too yellow nor too blue.

The general Color Rendering Index (CRI) measures the color appearance of objects under a particular light source compared to their appearance under an appropriate reference source, such as natural daylight or a common incandescent light source. A CRI of 100 represents perfect color fidelity to the reference. A light source with a high CRI is able to faithfully represent many different shades of color and is said to have a good color rendering and is showing the colors accurately. A surgical light with a CRI of 92 or more is considered to have excellent color rendering ability. Generally, it is difficult to see differences of less than 5 points in CRI with the unaided eye, although sophisticated optical test equipment can easily measure CRI with much higher precision.

The general color rendering index is actually an average of eight special color rendering indices for various pastel shades. The special color rendering index for the 9th color sample, R₉, is not included in the general average, but is very important to surgeons because it represents the ability of a light source to render deep, saturated red. Most older generation surgical lights use an incandescent (tungsten halogen) lamp and have a CRI in the mid-90s. However, their R₉ values are often in the low 70s. The reason for this is related to the way in which the older incandescent lights generate and then filter the radiation to reduce heat. By their very nature, halogen bulbs emit a lot of infrared (IR) radiation, which produces a lot of heat but isn’t visible and therefore doesn’t help illuminate the surgical site. Consequently, manufacturers reduce the IR radiation (and the resulting heat) that reaches the surgical field by using dichroic coatings that reflect the visible light while allowing the IR

radiation to pass through the reflector. Unfortunately, by trying to filter out all of the bad IR, invariably some of the good, visible red light gets filtered out as well, directly leading to a poor color rendition of deep, saturated reds, as indicated by a low R_9 .



Surgical lights using Light Emitting Diode (LED) technology have been designed such that the lights do not emit infrared radiation, yet provide good light output in the red portion of the spectrum. As a result, manufacturers can avoid the use of filters and can provide surgical lights that radiate much less heat than even filtered incandescent bulbs, while maintaining good color rendering of deep reds.

Color Rendering Indices

LED surgical lights can provide a general CRI in the mid-90's like an incandescent light, but with an R_9 that is also in the mid-90's, while still emitting only 75% of the radiant heat of traditional incandescent surgical lights.

Adjustable Color Temperature

One of the most recent trends in LED-based surgical lighting is to provide users with the ability to adjust the color temperature of the surgical light before or during a procedure. This feature was impossible, or at least highly impractical, to provide with conventional incandescent light sources but is relatively easy to provide with LEDs. The clinical benefits of adjustable color temperature are not yet well established, although different individuals may have different color temperature preferences. Surgical lighting manufacturers have suggested that using a specific color temperature for certain tasks may promote color discrimination and help surgeons concentrate better. As the color temperature varies, it is important that illuminance levels not be decreased, irradiance levels not be increased, and the color rendering properties of the light be maintained.

SURGICAL LIGHTING USE

Focusing and Positioning

The surgical team is responsible for positioning, aiming and focusing the surgical light. If visibility is compromised, then the risk of undesired outcomes increases. Equipment other than the surgical lighting systems, such as reflective surgical instruments, can also affect visibility.

To reduce direct or specular light reflection, instruments should be ebonized (black finish) or anodized (matte finish). Of course, the design and features of the surgical lighting system can also affect visibility, for instance, by enabling easy and quick focusing so that the negative effects associated with variations in light intensity can be minimized. A well-designed lighting system will provide a means for sterile re-positioning of lights during a case. This may be accomplished through the use of a disposable sterile cover placed over the lighthandle or a removable, sterilizable lighthandle. In either case, the staff must understand how to properly secure the lighthandle to the lighthouse and attach the sterile cover, if used, with proper sterile technique. Failure to properly engage the light handle or sterile cover may result in the lighthandle or cover falling from the lighthouse during the procedure.

Surgical lights are usually designed with non-sterile handles or ledges on the lighthouse housing that enable easy maneuverability by the circulating nurse. However, exact aiming of the surgical light by the



circulating nurse may be difficult, since he or she may not be able to see the target area well and the exact position of the beam may have to be estimated.

STERIS Corporation has introduced a patented design that allows the surgeon to control the intensity of the surgical lights, including the ability to turn them on and off, directly from the lighthouse. Some of the control functionality that had previously been available only on the wall control unit and therefore only accessible to non-scrubbed

personnel is now available on the handle of the surgical light. These control buttons are located under the sterile light handle cover and are easily accessible to the surgeon while maintaining sterile technique.

Overhead surgical lights must be easy to position even though x-ray, monitoring screens, and anesthesia equipment compete for the available ceiling space. Operating rooms must be carefully planned so that all the ceiling-mounted equipment may be easily maneuvered while minimally interfering with each other. The surgical luminaire must be suspended in such a way to allow complete drift-free rotation over and around the operating table. Surgical lights should never be allowed to bump into walls or other equipment while being positioned.

The surgical lights may be positioned directly behind the surgeon's head or shoulder; however, an alternative that many find useful is positioning one light to the surgeon's right and one to the surgeon's left, both aimed at the operative site at an angle about 45°-60° below horizontal. For an abdominal incision, this means placing one lighthouse over the patient's head and one over the patient's knees. This minimizes shadows in the surgical field while allowing the surgical team the best access to the surgical site.

Surgical lights are designed to provide the best possible beam in terms of peak illuminance and uniformity when the lighthouse is positioned at a certain distance from the surgical site. This distance may be referred to as the focal length or intended working distance of the lighthouse. At distances closer or further than this ideal distance, the beam will be larger in diameter and lower in intensity. Therefore, it is important to position the lighthouse at the proper location in order to achieve optimal performance. By design, this focal length may be either fixed or variable. If the focal length is fixed, it is important that the pattern size and intensity be relatively insensitive to the positioning distance, so that the lighthouse will not require very precise positioning in order to achieve acceptable performance. This is determined by the depth of field (also known as the depth of illumination), which is the distance over which the illuminance remains above a certain percentage (typically, 20% or 60%) of its peak value. If the focal length is adjustable, the user can maintain good lighting performance over a wide range of working distances by manually adjusting the lighthouse which positions the light sources within the lighthouse and effectively focuses the light. In many designs, changing the pattern size is the same thing as changing the focal length, that is, the distance at which the various beams of light coming from the lighthouse overlap to produce the smallest, brightest beam.

Laminar Air Flow Compatibility

Some operating rooms are equipped with laminar air flow systems to reduce the risk of infection by providing a steady flow of air over the patient that will carry any airborne contaminants away from the surgical site. Analyses have shown that the desired airflow patterns around the patient can be disrupted by equipment suspended from the ceiling, especially large surgical lights which are commonly placed directly over the patient and therefore directly in the airflow from the ceiling. Objects in the air flow will cause a stagnant zone to form on the downstream side of the obstruction which may trap airborne contaminants, rather than allowing them to be swept away from the patient. Therefore, when laminar airflow systems are in use, additional care must be used when positioning the surgical lights. In this case, it is particularly important to place the lights as far outside of the direct airflow as possible and at an angle above the patient and not directly overhead to reduce the size of the downstream stagnant region and make sure any stagnant region that does develop will not be directly over the surgical site.

Eye Fatigue

Visual fatigue, commonly referred to as eye fatigue and more scientifically as asthenopia, is a frequent problem for surgeons who must focus on small details of the surgical site for long periods of time under challenging lighting conditions. Our eyes adapt to the amount of light they receive by changes in pupil size as well as changes in the sensitivity of the rods and cones in the eye that are responsible for vision. The pupil can change size quickly in response to the amount of light striking the retina, whereas visual adaptation due to changes in sensitivity is a much slower process. Rapid and repeated changes in pupil size occur when the field of view includes sources of glare or wide ranges in brightness. It is this repetitive muscle activity in the eye which contributes to the feeling of eye fatigue. Therefore, the lighting environment plays a central role in the rate and degree of visual fatigue. However, many other factors contribute as well; for example, the close concentration and attention to detail needed to perform challenging procedures with speed and accuracy can cause a reduction in blink rate, making the eyes drier than usual and contributing to discomfort. Temperature, humidity and the presence of airborne particles, such as volatile organic compounds, can also contribute to visual discomfort.

Although eye fatigue is an inherent part of the practice of surgery, the rate at which it develops and the degree of discomfort or loss of visual acuity can be reduced through the careful design and control of the surgeon's visual environment. An appropriate amount of general illumination is needed to provide a comfortable surrounding brightness that will minimize contrast with the highly lighted operative area. General recommendations for minimizing eye fatigue are based on the luminance of various surfaces in the OR, that is, the amount of light coming back from these surfaces into the surgeon's eyes. Luminance depends on how much light strikes the surfaces as well as how much of it is reflected. Therefore, both high light levels and highly reflective (shiny) surfaces contribute to the onset of eye fatigue.

Ideally, the luminance ratio should be no greater than 3:1 between the surgical wound and the surgical field, no greater than 5:1 between the surgical field and the instrument table or surrounding surfaces, such as the walls and ceiling.⁶ The surgical wound is often highly absorbing, whereas the patient's skin or the surgical drape immediately surrounding the wound may be much more reflective. This may cause the area surrounding the wound to be brighter than the wound itself and may contribute to eye fatigue. Most surgical lights allow for the pattern size to be adjusted and it is important to use this feature to set the pattern size to completely fill the wound but not spill over onto the more highly reflective surfaces outside the wound which could distract the surgeon or lead to eye fatigue. Although it is unavoidable that instruments be placed in the beam of light, the use of matte or black anodized surfaces can help to reduce glare. The surgical light should be set so that the light levels are as low as possible while still providing adequate

illumination of the surgical site. It is recommended that the surgical lights be turned on at a mid-range setting at the beginning of each case, rather than on full intensity from the beginning. The intensity can then be increased should more light be needed during the procedure.

Maintenance and Care

Surgical overhead lighting systems require regular attention and care involving:

- > Infection prevention measures to control infection transmission
- > Preventive maintenance to maximize the effectiveness of the light

Dirt accumulation within surgical luminaires can occur on the lenses, lamps, or reflectors. Dust that has accumulated on the optical components can decrease the output of the light while dirt that has accumulated on the operating room walls and ceilings can reduce reflectivity and can decrease the general room lighting levels. Most surgical lights have a sealed lighthouse to prevent dust from entering or leaving the lighthouse; however, dust that has settled on the outer surfaces of the luminaire can become dislodged during positioning and may possibly contaminate the sterile field. Ceiling-mounted lights suspended from a central pedestal or hub are preferred over track suspensions as dust can easily settle along the light tracks and then fall into the surgical incision when the light is repositioned. Meticulous, daily cleaning can prevent this problem.

The AORN Recommended Practices for Environmental Cleaning in the Surgical Practice Setting, Recommendation I states: "The patient should be provided a clean, safe environment".⁷

Recommendation I.b. states: "All horizontal surfaces in the OR (e.g. furniture, surgical lights, booms, equipment) should be damp dusted before the first scheduled surgical procedure of the day".

Dust and lint are deposited on horizontal surfaces. Proper cleaning of these surfaces will help reduce airborne contaminants that may travel on dust and lint. All horizontal surfaces within the OR (e.g., furniture, surgical lights, equipment) should be damp dusted before the first scheduled surgical procedure of the day with a clean, lint-free cloth moistened with an Environmental Protection Agency-registered hospital disinfectant.

Detergent germicides or disinfectants may be used to wipe off the surfaces of the surgical lights. Disinfectant solutions that are listed in the operator's manual for each brand of surgical lighting system can be used without causing discoloration, pitting, staining, or deformation on the light or lens surfaces. These cleaning solutions have been tested for material compatibility and effectiveness. The manufacturer's instructions should also be followed regarding concentrations of germicidal solutions. The use of an alcohol product or aerosol spray cleaner containing a substantial amount of alcohol in the formula may damage the polycarbonate lens. When a control center keypad is cleaned, betadine solutions can cause discoloration to the keypad and display.

When daily damp dusting of the surgical lights is performed, an inspection of the lighting system's surfaces can also be done. When the finish on a surgical luminaire becomes cracked or peeled, then the potential for paint chips to fall into the sterile field becomes greater. Contact between the lighthouse and other furniture and equipment (such as IV poles or portable imaging equipment) can damage the lighthouse's surface and can chip or crack the finish. Regular inspection of the surgical lights will note any flaking, cracking, or peeling. The manufacturer should be contacted for care instructions. Sometimes a custom touch-up paint can be applied.

The lighting system covers should not be removed nor should service be performed by inexperienced or unqualified personnel. The operator's manual and service manual should be referenced before performing any preventive maintenance or service on the lights.

Practices that address proper maintenance and care are reviewed below:

- > Surgical lights should be damp dusted before the first scheduled surgical procedure of the day with a clean, lint-free cloth moistened with an EPA-registered hospital disinfectant.
- > Use only disinfectant solutions that are listed in the operator's manual to avoid discoloration, staining, or pitting.
- > Regularly inspect the surface of the surgical lights to note any flaking, cracking, or peelings. The manufacturer should be contacted for care instructions.
- > Place the sterile lighthandle cover securely on the light post to prevent the cover from falling from the lighthouse during the procedure.
- > The manufacturer's written instructions should be followed when replacing a lamp (the lighthouse must be turned off and cooled, the glass on the new lamp must not be touched with bare fingers, the old lamp must be disposed of properly).
- > Check the functioning of the emergency power system periodically, especially when surgical lighting is connected to it.
- > The operator's manual should be referenced before performing any preventive maintenance or service on surgical lights.

SUSTAINABILITY OR "GREEN INITIATIVES"

Many hospitals have been challenged to reduce energy consumption and adopt green initiatives. They are taking on these challenges of making their buildings more environmentally friendly and reducing their carbon footprint while making their hospitals more efficient. They are accomplishing these goals by implementing recycling programs, improving energy efficiency standards and reducing or eliminating products containing mercury, polyvinyl chloride or volatile organic compounds. Advancements in technology, such as improvements in surgical lighting, are also helping healthcare facilities meet these challenging goals. The recent introduction of LED-based surgical lights has allowed hospitals to reduce operational costs, reduce harmful emissions through reduced energy consumption, and extend the normal product life cycle of surgical lights. Additionally, several of the surgical lighting companies maintain domestic manufacturing which not only reduces transportation costs and carbon footprint, but also creates and sustains jobs domestically.

Operational Costs

The health care field is a big energy consumer, with hospitals using about two and a half times as much power as similar commercial buildings. While lighting consumes only about 1 percent of the energy used in hospitals, the fact that lights are typically on 24 hours a day, seven days a week, offers an opportunity for savings. LED Saving Solutions recently estimated that if a single hospital replaced hospital lightbulbs with LEDs, they could save about \$4.5 million annually.⁸

Emission Reduction

LED Saving Solutions also determined that if a hospital replaced all of its lightbulbs with LEDs, they could also reduce about 3.5 million pounds of greenhouse gases over a seven year period.⁹

Energy Efficiency

The efficiency of a light source is a measure of how much light is produced for a given amount of electrical input power and is commonly expressed in lumens per watt (LPW). The efficiency of the luminaire is a measure of how much of the light initially generated by the source ends up in the beam of light emitted by the luminaire and is commonly expressed as a percentage. Manufacturers of surgical lights seek to use the highest efficiency light sources and design their luminaires to provide the highest possible system efficiency for best overall performance and lowest operating costs.

LED lights consist of an array of light-emitting diodes. These diodes typically use less electricity than incandescent light bulbs with similar light output. Utilizing LED lights will reduce your power consumption, utility bills and environmental footprint.

Product Life

Compared to incandescent lamps, LEDs have an extremely long life span, which reduces replacement costs, downtime and disposal concerns. Manufacturers claim that LEDs can last for 30,000 hours of usage or more. This is 3,000% longer life span than halogen bulbs. The longer life span eliminates the interruptions and delays caused by burned-out halogen bulbs as well as the expense of buying, stocking and replacing bulbs that have an expected life span of 1,000 hours.

Local Manufacturing

Local manufacturing reduces transportation costs and reduces total emissions. Such solutions have a positive environmental impact and also helps create domestic jobs. While the majority of surgical light manufacturers manufacture overseas, there are suppliers who are manufacturing lights domestically.

INTEGRATION OF SURGICAL LIGHTS WITH OTHER OR EQUIPMENT

Surgeons operate with their vision guiding them and operating rooms became early adopters of video and display technology. In the 1970's, a large video camera was suspended from the ceiling by a rope in the OR. Today, the OR continues to be at the forefront of video and display technology. Dramatic advances in technology have radically changed the OR and now high definition cameras are mounted off surgical lighting suspensions with the signal routed throughout the room. Large format, high-definition, flat panel monitors are positioned throughout the room. The marriage of technology and surgery has changed how medicine is practiced.

Fully integrated operating rooms are now expected by surgeons who are looking to see better for better patient outcomes. To accomplish this goal they look for higher definition cameras to capture images, better methods of data transmission and higher definition displays.

Integration

Integration provides a simple, single point of control to route video images from such sources as surgical cameras, C-arms and PACS to any display in the room or even to a remote location. Integration can also control OR infrastructure - like surgical lights, a music system, or even a teaching and teleconferencing system.

HD Technology

High resolution cameras and monitors allow surgeons to see more detail, which improves their performance. High-resolution cameras allow surgeons to see critical highlights, mid-tones and shadows. High-definition monitors maintain image quality by displaying the highest resolution and best color saturation. Today, there are many sizes and resolutions available for any application. Fiber optic inputs for all signal types provide unrivaled visualization from any source to any display in the room.

TRENDS IN PURCHASING PREFERENCES

Determining the most efficient and cost-effective surgical lighting system can present a challenge to the surgical team. If their current surgical lighting systems are the benchmark for future purchases, the team must take into consideration that surgical lighting systems vary with age and options. For example, a surgical light in OR 3 may be more than 15 years old, while the surgical light in OR 9 may be new. In either case, the surgical team must understand the limitations of the current systems and the advances that have been made in newer ones.

Costs versus Benefits

The initial purchase of new technologies such as LED surgical lights cost more than traditional lighting. While pricing varies, LED lights can cost as much as 20% to 30% more than traditional halogen bulb lights. While the difference in price might seem problematic, the operational cost savings of LED lights such as energy efficiency, life span and disposal costs save money over the long term.

Energy efficiency is one such advantage. A typical halogen light may use 180 watts of power compared to an LED light that may use only 130 watts.

LEDs are more durable than halogen lights. Halogen lamps last around 1000 hours of typical usage, but there is a large variability from lamp to lamp, even under nearly identical conditions. LED light sources are entirely different from incandescent lamps in terms of life. An LED will not typically burn out in an instant, but rather the light output will decay gradually, but continually, during its lifetime. Typical LED-based surgical lights have rated lifetimes from 20,000 to 40,000 hours.

Lower disposal costs also reduce your operating costs. Halogen lamps last around 1000 hours before burning out and needing to be disposed of, whereas LEDs don't need to be replaced and disposed of for at least 20,000 – 40,000 hours.

Advances in Technology

New technology to support advances in surgical procedures, techniques and preferences makes it necessary to consider surgical lights as part of a complete surgical lighting and visualization system for the operating room. There are many factors to consider when purchasing a surgical lighting system, for example:

- > Ability to transfer video signals and power to multiple flat panel monitors
- > Ability for technical or product upgrades
- > Ability to incorporate video camera systems
- > Ability to integrate into endoscopic automation systems
- > Adequate and consistent illumination of the surgical field
- > Excellent intensity ranges for brightness without glare
- > Excellent cavity illumination
- > Maximum shadow control, that is, minimum loss of light and distortion of the pattern due to obstructions
- > Elimination of excessive heat in the surgical field
- > Adequate general room illumination even in minimally invasive surgery
- > Adequate size of the light field and depth of field

- > No distortion of colors - natural color rendition
- > Flexibility, reach and maneuverability of the luminaire, including low lateral positioning, while being stable and drift-free
- > Sterile control that is not easily contaminated
- > Non-sterile “grasping” surface
- > Purchase price of the surgical light (cost-effective)
- > Maintenance and operating costs (service contracts)
- > Lamp replacement costs and frequency of bulb changes
- > Easy to clean
- > Easy to change light bulb (automatic lamp changeover)
- > Safety in changing light bulb
- > Standardization
- > Easy and cost-effective installation

Local Manufacturing

The economic benefits of buying locally are fairly straightforward. It reduces transportation costs and puts more money into the local economy. The full benefits from buying locally are:

- > Less packaging and package waste
- > Lower shipping costs, which conserves fuel
- > Promotes/supports the local community
- > Keeps dollars in the local economy

Each factor needs to be addressed carefully while noting the safety measures that must be considered.

SUMMARY

Advancements in surgical lighting systems have been welcomed and recognized as promoting better surgical outcomes through enhanced visualization. Refinements have allowed the surgical team members to precisely control the intensity of the light along with manipulating other variables to provide the best quality lighting available. Because of the advancements in lighting technology combined with increased manual control options, safety must be addressed to minimize and eliminate errors and injuries. Surgical team members must be aware of these enhanced capabilities so that the advantages and limitations associated with the use of high intensity surgical lighting systems can be achieved.

As operative procedures have become more complex, so have surgical lighting systems. Complexity requires improved skills and attentiveness to safety considerations. Surgical lighting technology will continue to progress, therefore, surgical team members are urged to carefully review, and become familiar with, the safe and proper operation of these surgical lights.

This Study Guide has been planned, produced, and approved as a continuing education (CE) activity. This material will be reviewed within two years of its release date and re-released, or its designation for CE credit will become invalid.

Glossary

Brightness

The attribute of the visual sensation related to the amount of light reaching the eye. In technical usage, the term brightness may be used to mean the luminance of a surface, although it is preferable to reserve the term brightness to mean the subjective sensation.

Color

The characteristic of light by which a person can distinguish a difference between two patches of light of the same shape and size. The apparent color is determined by the relative strength of different wavelengths of light. Names have been assigned for various colors of light depending on the dominant wavelength. For instance, light with a dominant wavelength in the range of 500-570 nm is considered green.

Color rendering index (CRI, R_a , R_9)

Measures the effect of a specific light source on the color appearance of the objects being illuminated by that source. A CRI of 100 is the highest possible value and indicates that the light source renders color in the same way as a particular reference source. Surgical lights must provide a CRI greater than 85 which ensures excellent color rendering for surgical applications. CRI may also be denoted as R_a , which represents the average of eight special color rendering indices for different pastel shades. R_9 is the special color rendering index for the ninth color sample, which is a deep saturated red. A high R_9 value is particularly important for surgical lights.

Color temperature (Correlated color temperature, CCT)

A temperature measured in Kelvin(K) that describes the apparent color of various shades of white light. Typical surgical lights have a color temperature around 4400 K.

Depth of field (or depth of illumination)

Indicates the length of the range of distances from the surgical luminaire for which the beam maintains its quality and usefulness. A large depth of field ensures that the pattern size of the beam and the amount of light are not very sensitive to the distance that the lighthouse is positioned from the surgical site.

Discharge lamp (or gas discharge lamp)

A type of artificial light source that passes electrical current through an ionized gas, creating an electrical discharge that produces radiation that may be directly visible or converted to visible light through the use of phosphors.

Efficiency

The ratio of visible radiant power, typically measured in lumens, to the electrical input power typically measured in watts. The efficiency of a light source is typically expressed in lumens per watt (LPW).

Fluorescent lamp

A specific type of gas discharge lamp that produces light by using a low-pressure mercury discharge to generate ultraviolet radiation that is then transformed into visible radiation using a fluorescent coating on the wall of the lamp to shift the wavelengths.

Focal length

The distance from the surgical luminaire at which the beam of light forms the smallest spot size and has the highest illuminance. The focal length represents the intended working distance for the surgical luminaire, since positioning the luminaire at (or near) this distance from the surgical site provides the best possible illumination.

Footcandle (fc)

A unit of illuminance equal to 1 lumen / ft². One fc = 10.76 lx.

General lighting

Lighting designed to provide an adequate level of illumination throughout a large area, such as an entire room.

Illumination

The general term for light on a surface that enables a person to see that surface.

Illuminance

The surface density of light striking a surface, that is, the amount of light per surface area. Illuminance is typically measured in lux or footcandles. This term is not used to describe surfaces that are generating light (see luminance).

Incandescent lamp

A type of artificial light source that produces light by passing an electrical current through a filament wire, causing it to get hot enough to radiate in the visible portion of the electromagnetic spectrum.

Irradiance

The surface density of radiant power striking a surface, that is, the amount of power per surface area. Irradiance is typically measured in watts per square meter (W/m²).

Lamp

An artificial source of light, such as an incandescent lamp or fluorescent lamp.

LED (light emitting diode)

A type of artificial light source that produces light by passing electrical current across the junction between dissimilar solid materials. LEDs are part of a more general category of light sources called solid state lighting.

Light

Radiant energy in the portion of the electromagnetic spectrum between 380 nm and 770 nm that is detected by the human retina and produces a visual sensation. The term "light" should be restricted solely to radiation in the visible region of the spectrum, not ultraviolet (UV) or infrared (IR) radiation. The term "light" is also commonly used to refer to the lamp or luminaire that is producing the light.

Lumen (lm)

The unit of luminous flux used to measure the amount of visible radiant power. The amount of lumens produced by a light source is one common way to measure how much light is available for seeing.

Luminaire

A complete lighting unit consisting of one or more light sources (lamps), components to position and aim the light, and means to connect the lamp to the power supply; also referred to as a lighting fixture or lighthouse.

Luminance

The amount of light that is emitted or reflected from a surface in a certain direction; also called brightness.

Lux (lx)

A unit of illuminance equal to 1 lumen / m². One lx = 0.0929 fc.

Nanometer (nm)

A unit of length equal to 10^{-9} meters, commonly used for describing the wavelength of light.

Quality of lighting

Pertains to the distribution of the light within an area that contributes to the visual performance of the light.

R₉

R₉ is the special color rendering index corresponding to the 9th color sample used to measure color rendering. While R₉ is not included in the general color rendering index (CRI), it is very important in surgical applications because it represents the ability of a light source to render deep, saturated reds.

Radiant Energy

The amount of heat produced by a light source due to both visible and invisible (infrared) radiation. The amount that reaches the patient depends on both the amount of radiant energy created by the light source as well as the efficiency of the lighting system to filter out the heat.

Shadow reduction (or shadow control)

The ability of a lighting system to minimize sharp shadows in the beam due to obstructions between the light source and the surgical site, such as the heads and shoulders of the surgical team members.

Spectrum

A range of wavelengths. The visible portion of the electromagnetic spectrum contains wavelengths between 380 nm and 770 nm.

Task lighting

Lighting designed to provide a sufficient illumination in a specific area - such as the work surface of a desk or the surgical site in an OR - to perform a particular task at that location. Task lighting provides illuminance levels that often far exceed those of general illumination.

Wavelength

Distance between two successive peaks on a periodic (repeating) wave. The wavelength of light is typically measured in nanometers. The dominant wavelength of a light beam determines the apparent color of the light.

References

- 1 IEC 60601-2-41, 2nd edition, Medical electrical equipment – Part 2-41: Particular requirements for basic safety and essential performance of surgical luminaires and luminaires for diagnosis, 2009, p. 21.
- 2 IESNA Health Care Facilities Committee, Recommended Practice for Lighting for Hospitals and Health Care Facilities, ANSI/IESNA RP-29-06, New York: Illuminating Engineering Society of North America, 2006, p. 19.
- 3 IEC 60601-2-41, 2nd edition, Medical electrical equipment – Part 2-41: Particular requirements for basic safety and essential performance of surgical luminaires and luminaires for diagnosis, 2009, p. 33.
- 4 Ibid., p. 33.
- 5 Operator Manual, Harmony® LED or LA Surgical Lighting and Visualization System, STERIS Corporation, 2007, p. i.
- 6 IESNA Health Care Facilities Committee, Recommended Practice for Lighting for Hospitals and Health Care Facilities, ANSI/IESNA RP-29-06, New York: Illuminating Engineering Society of North America, 2006, p. 17.
- 7 Recommended Practices for Environmental Cleaning in the Surgical Practice Setting, 2004, Denver, CO, Association periOperating Registered Nurses (AORN), p. 273-279.
- 8 Seeking Green in Bio & Medical Products, (BioPhotronics Oct 2009, <http://photonics.com/Content/ReadArticle.aspx?ArticleID=40011>)
- 9 Ibid.

Review

- Which of the following is NOT a benefit of LED surgical lights as compared to standard incandescent surgical lights?
 - Longer life
 - Less radiated heat
 - Higher color temperature
 - Thinner lighthead
- The light output from an LED will remain relatively constant over its life until the light completely goes out in an instant, whereas the light output from an incandescent light will gradually dim over its life but will rarely go completely out in an instant.
 - True
 - False
- During the past few decades, the peak illuminance of an individual surgical light has:
 - increased significantly
 - stayed about the same
 - decreased significantly
 - reached the upper limit of the international standard for surgical luminaires
- Decreasing the pattern size is typically an effective means of reducing the amount of thermal energy delivered to the surgical site and reducing the risk of thermal burns.
 - True
 - False
- Visible light does not provide any heat to the surgical site; only the invisible infrared radiation provides heat, so just reducing the amount of visible light will not reduce the risk of thermal burns.
 - True
 - False
- To prevent tissue dryness or burns, the following practices should be employed:
 - When using a higher illumination level, decrease the amount of exposure of the light on the tissue
 - When overlapping light fields, decrease the intensity and duration of exposure of the light
 - Keep tissue moist and cool when possible using irrigation and wet sterile sponges
 - All of the above
- What feature of a surgical light is described by its R₉ value?
 - How bright it is
 - How much heat it emits
 - How well it prevents sharp shadows from appearing in the beam
 - How well it renders deep, saturated red colors
- Which of the following are known to significantly increase eye fatigue?
 - Low color rendering index (CRI)
 - High color temperature (CCT)
 - Shiny instruments that cause glare
 - Large differences in brightness between the surgical site and the immediately surrounding area.
- At the start of a procedure, it is recommended to:
 - Turn the lights on at a mid-range intensity and increase the light output during the procedure if needed.
 - Turn the lights on at highest intensity to make sure the surgeon will have enough light.
- Why is it important to regularly clean the outer surfaces of surgical lights and the suspension systems that support them?
 - To keep the manufacturers warranty in effect.
 - To keep the lighting system from wearing out prematurely
 - To maintain the capability for full light output
 - To reduce the risk that contaminants will fall from the lighthead into the surgical field.

- Answers to Review Questions & Section Sources:
- C (Light sources for surgical lighting – Light Emitting Diode)
 - B (Light sources for surgical lighting – Lamp Life)
 - A, D (Surgical lighting safety – Light and heat)
 - B (Surgical lighting safety – Light and heat)
 - B (Surgical lighting safety – Light and heat)
 - D (Surgical lighting safety – Light and heat)
 - D (Surgical lighting performance – Color)
 - C, D (Surgical lighting performance – Eye fatigue)
 - A (Surgical lighting performance – Eye fatigue)
 - C, D (Surgical lighting safety – Maintenance and care)

Registration Evaluation Form

Study Guide #16: Advancement in Surgical Lighting Systems and Their Clinical Implications

Last Name

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RN/LPN/LVN License Number (Circle one: RN - LPN - LVN)

Non-RN: License or Social Security Number

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To what extent did the study guide meet the 2 stated objectives below?

- | | | | | | |
|--|---|----------------------------|----------------------------|----------------------------|----------------------------|
| 1. Define terms that characterize illumination and surgical lighting technology. | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
| 2. Describe safety measures needed when using today's overhead surgical lights. | <input type="checkbox"/> 1 | <input type="checkbox"/> 2 | <input type="checkbox"/> 3 | <input type="checkbox"/> 4 | <input type="checkbox"/> 5 |
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