Tactical Lighting in Special Operations Medicine: Survey of Current Preferences

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ABSTRACT

Success in Special Operations Forces medicine (SOFMED) is dependent on maximizing visual capability without compromising the provider or casualty position when under fire. There is no single ideal light source suitable for varied SOFMED environments. We present the results of an online survey of Special Operations Medical Operators in an attempt to determine strengths and weaknesses of current systems. There was no consensus ideal hue for tactical illumination. Most Operators own three or more lights, and most lights were not night vision compatible. Most importantly, nearly 25% of respondents reported that lighting issues contributed to a poor casualty outcome; conversely, a majority (50 of 74) stated their system helped prevent a poor outcome. Based on the results of this initial survey, we can affirm that the design and choice of lighting is critical to SOFMED success. We are conducting ongoing studies to further define ideal systems for tactical applications including field, aviation, and marine settings.

Keywords: *lighting, tactical, dark adaptation, contrast sensitivity, illumination*

Introduction

Currently, no Army regulations govern lighting applications for tactical medicine. Determination of the ideal lighting system for a given application is dependent on several factors. Key optics variables include the wavelength and intensity of the emitted light. Physiologic concerns include effects of lighting on visual acuity and task performance, contrast sensitivity, stereopsis, and dark adaptation, as well as platform/environmental specific needs (ground versus aviation). Practical considerations for medicine in austere applications include weight and durability of the system, compatibility with night-vision systems, and battery life before recharge or replacement. Ultimately, Operator reports of "what works" combined with a sound understanding of optics and the physiology of vision lead to rational development of an ideal multifunction, multiapplication platform for tactical lighting.

We seek to define the current tactical lighting needs for SOFMED personnel of all branches and combat environments. Our ongoing studies currently include laboratory clinical trials of various lighting systems as well as field testing with state-of-the-art trauma simulators. In this initial publication, we report the results of an online survey of tactical medical lighting preferences and their impact on casualty outcomes as described directly by SOFMED providers.

Methods

A survey was made available to the SOMA community via a link posted on the JSOM site (http://www.surveymonkey.com/s/837G2YN). A commercially available survey-processing website (www.surveymonkey.com) was used. All responses were confidential and made without recording personally identifying information (PII). This was an initial study designed to identify current problems, trends, and performance needs/deficits of tactical lighting systems in use by Operators of all specialties. We chose to avoid statistical analysis beyond descriptive assessment in this pilot project, in anticipation of future larger studies. We intentionally chose to keep questions about casualty outcomes free of operational and medical details. Our intent was only to determine if current lighting systems are helping and/or hindering provider success as perceived and reported by SOFMED personnel. Data are presented as the actual number of responses in each category for a given question.

The survey consisted of 10 questions with response choices as below. It was estimated that completion online would take approximately 5 minutes of the respondent's time.

1. How many tactical lights do you have? (choices: 1, 2, 3, ≥4)
2. Are you satisfied with your current system? (yes/no)

3. Are you satisfied with battery life? (yes/no)
4. Are you satisfied with current illumination intensity/control? (never/sometimes/mostly/always)
5. Is your current system NVG compatible? (yes/no)
6. What is your primary setting? (field/aircraft/ground vehicle/marine naval/other)
7. Has a lighting issue contributed to a poor outcome? (yes/no)
8. Has your lighting system helped prevent an otherwise likely poor outcome? (yes/no)
9. How often do you use white light in a tactical environment to treat casualties? (never/seldom/often/always)
10. What is your preferred tactical illumination hue? (red/green/blue)

Access to the website link was made available from March through July 2013, with routine postings and updates on the SOMA website inviting members to complete the survey. No password was needed and no PII data were collected at any time.

Results

This survey revealed several interesting findings about SOFMED tactical lighting. Table 1 shows that most Operators have more than one light (95%), and nearly half of the respondents have four or more (70%). The majority (57 of 74, 77%) were mostly or always satisfied with their systems (Table 2), although battery life was slightly less favorable, with 50 of 74 (68%) stating being mostly or always satisfied (Table 3). Most users (50 of 74, 68%) were satisfied with the illumination and intensity controls of their current favored device (Table 4), while only 24 of 74 (32%) used systems that were night vision goggles (NVG) compatible (Table 5).

Table 1 *How Many Tactical Lights Do You Have? (N = 74)*

	No. of Tactical Lights			
	One	Two	Three	Four+
No. of respondents	4	18	19	33

Table 2 *Are You Satisfied With Your Current System? (N = 74)*

	Satisfied With Current System			
	Never	Sometimes	Mostly	Always
No. of respondents	0	17	53	4

Table 3 *Are You Satisfied With Battery Life? (N = 74)*

	Satisfied With Battery Life			
	Never	Sometimes	Mostly	Always
No. of respondents	5	23	42	4

Table 4 *Are You Satisfied With Current Illumination Intensity/Control? (N = 74)*

	Satisfied With Current Illumination Intensity/Control	
	Yes	No
No. of respondents	50	24

Table 5 *Is Your Current System NVG (Night Vision) Compatible? (N = 74)*

	Current System NVG (Night Vision) Compatible	
	Yes	No
No. of respondents	24	50

Table 6 shows the distribution of tactical environments with the majority of SOMA respondents functioning in the field (52/74, 70%), with some air and ground vehicle as well as marine/naval Operators also represented. The survey also had self-identified primary settings, including a battalion aid station and civilian law enforcement.

Two of the most important questions for medical personnel followed. Table 7 shows that 17 of 74 (23%) respondents felt that lighting issues contributed to poor outcomes (see also Table 8).

Tables 9 and 10 show the distribution of choices in illumination hue. This includes using white light (Table 9) and a broad range across red, blue, and green lights

Table 6 *What Is Your Primary Setting? (N = 74; "other" includes civilian law enforcement [1] and battalion aid station [1])*

	Your Primary Setting				
	Field	Aircraft	Ground Vehicle	Marine/ Naval	Other
No. of respondents	52	9	8	3	2

Table 7 *Has a Lighting Issue Contributed to a Poor Outcome? (N = 74)*

	Lighting Issue Contributed to a Poor Outcome	
	Yes	No
No. of respondents	17	57

Table 8 *Has Your Lighting System Helped Prevent an Otherwise Poor Outcome? (N = 72)*

	Lighting System Helped Prevent an Otherwise Poor Outcome	
	Yes	No
No. of respondents	52	20

Table 9 *How Often Do You Use White Light in a Tactical Environment to Treat Casualties? (N = 74)*

	Use White Light in a Tactical Environment to Treat Casualties			
	Never	Seldom	Often	Always
No. of respondents	9	34	30	1

Table 10 *What Is Your Preferred Tactical Illumination Hue? (N = 68)*

	Preferred Tactical Illumination Hue		
	Red	Blue	Green
No. of respondents	20	32	16

(Table 10), with blue being favored in 32 of 68 (47%) responses.

Discussion

Relevance of Survey Findings

We were not surprised to learn that the majority of respondents have at least three or more lights. This may indicate that Operators prefer "back-ups" of preferred units in case of malfunction or damage. Conversely, it may also indicate a lack of ideal unit resulting in multiple different systems for unique applications. Ideally, one light could be engineered as a tunable device for all common applications. As Table 2 shows, the vast majority of responses were sometimes or mostly satisfied with their current tactical light, which argues against possession of multiple units due to none being ideal. Table 3 shows that 46 of 74 Operators were mostly or always satisfied with battery life. From an engineering stance, it is always a goal to improve performance; this may be met by minimizing weight and maximizing durability and battery life while controlling cost per unit.

Task performance is ultimately dependent on Operator functional vision, which is a function of visual acuity and therefore dependent on illumination, hue, and contrast sensitivity. About two-thirds (50 of 74) were satisfied with the illumination intensity and control of their preferred unit. Unfortunately, about two-thirds (50 of 74) were not compatible with NVGs, highlighting a gap in functional application requiring further research and development (Table 5). While most (51 of 74) Operators reported a primary tactical setting as field based (Table 6), clearly the demands of aviation and maritime versus ground vehicle and field environments influence lighting design and performance needs.

Perhaps the most striking findings of this study involved casualty outcomes. We were very careful to construct questions 7 and 8 to be qualitative only, without asking details on the nature of a "poor outcome." The intent was to identify if Operators were either hindered or aided by their lighting system. SOFMED personnel are the best-trained and experienced providers in austere combat scenarios. The goal should be to provide the best equipment so that they can reach their potential as lifesavers. Table 7 shows that almost 25% (17/74) reported that lighting issues had contributed to a poor outcome, while Table 8 reports that lighting helped to avert a poor outcome in the experience of the majority, 52 of 72, of respondents. While it is reassuring to learn that excellent systems are available that promote high performance and lead to lives saved, the common occurrence of lighting associated poor outcomes must be reduced. In fairness to both the injured soldier and the combat medic, we are obligated to identify weaknesses and promote improvements; this study is the first step toward that goal.

The final two questions sought to identify gaps in the management of dark adaptation and visual acuity optimization. Table 9 shows a relatively even distribution in the use of white light in tactical environments biased toward never/seldom as opposed to often/always. Depending on the intensity of illumination, white light can compromise dark adaptation. Table 10 shows the preference between red, blue, and green light for tactical medical use, with the majority (32/68) choosing blue, while red (20/68) and green (16/68) lights were also used. The human eye is optimized to detect green light and most NVG systems are engineered with a green hue. The eye is least sensitive to red light, meaning it detects red light as dimmer when presented with an equal intensity of red, green, or blue. Preservation of dark adaptation is critical for SOFMED aviation where tasks include maintaining the ability to observe events outside the aircraft.

An online medical publication search revealed few relevant publications (search terms: *tactical, light, illumination, vision, performance, optimal, contrast, medical, task, dark adaptation*). Much of the data concerning lighting and vision performance are proprietary and remain in the realm of the automotive and aerospace industries. However, the basic physics of light and physiology of human vision (color and contrast) have been well investigated. A discussion of key scientific aspects of vision followed by a review of recent practical and applied studies from the literature follows.

Pertinent Optics and Vision Physiology

The visible light spectrum averages 550nm and spans 400–700nm, with ultraviolet (280–400nm) and infrared (700–1000nm) just outside the range of human visual detection. The human retinal cones (color perception) have maximal sensitivity to 555nm light. The retina has rods for dark vision and cones for color vision. The key to human vision is the stimulation of one rhodopsin molecule by one photon of light. Rhodopsins are optimized for stimulation by photons of red, green, or blue light—similar to a three-chip camera or "RGB" monitors. Red, yellow, and blue are primary colors, with green being a secondary color essentially blending blue and yellow in practical terms despite having a definite wavelength in the low 500nm range.[1]

Inherent to high-quality vision is contrast. Contrast is limited by the observer and is calculated as:

$$\frac{\text{Target luminance} - \text{background luminance}}{\text{Target luminance} + \text{background luminance}}$$

This makes sense, as a target and background of identical color and brightness would be impossible to distinguish. In a tactical setting, increasing luminance (brighter light) would increase contrast but may also betray one's position to the enemy. Therefore, we must seek other optical "tricks" to increase contrast, as it is contrast under low illumination that ultimately allows the medic or Operator to succeed.

There are four categories of lighting system analysis. First is the *light source* itself, with output measured in watts, candelas, or candles. Second is the *light beam* or luminous flux, measured in lumens. It is not clinically relevant, so we will defer further discussion. Third is *illuminance*. This is proportionate to the distance from light source to the target. It represents light falling on a surface and is measured in lux or lumens/m^2. Fourth and final is *luminance*. This light reflected from a surface, expressed as candelas/m^2, ft-lamberts, or milli-lamberts. In practical terms, a white paper may reflect 90% of incident light, while red paper would reflect much less (absorbing all but the reflected red wavelength light). Increased luminance is proportionate to the amount of illumination, the color of the target, and the illuminating light (intensity). The bottom line here for system design is that we must balance the risk for tactical compromise associated with higher illumination against providing the luminance required for task completion.

Another confounder is the concept of dark adaptation. When one quickly transitions from ambient/daytime illumination conditions to low-level/night, the retina needs time to adapt or switch from being optimized to detect the full spectrum of visible light under high illumination to the new dark conditions. Conversely, a dark adapted eye subjected to sudden bright light will be effectively blind for a short time. Intuitively, it would be ideal to change wavelength and not illumination intensity to improve contrast in the tactical setting.

Clinical examination of the retina using red-free (visible green) light allows improved sensitivity for detecting retina hemorrhages, as hemoglobin reflects red but absorbs green. Such hemorrhages also "stand out" against the retinal tissue—improved contrast resolution. Understanding the absorption spectra of a given fluid is the key to selecting the ideal wavelength for maximal contrast with minimal intensity of illumination. For example, if a Soldier has need to determine if a damaged vehicle leak is engine oil or transmission fluid at night under difficult conditions where high luminosity would compromise his position, it would be ideal to have a wavelength that with low luminosity would permit rapid and accurate discrimination of brown/black versus red fluid. Similarly, combat medics often need to distinguish fresh blood from other contaminants under suboptimal lighting without compromising their positions.

We cannot control an individual's best visual acuity or steropsis (beyond optimizing corrective lenses/refractive surgery), rate of dark adaptation, or maximal contrast sensitivity, but we can manipulate the environment to provide conditions allowing the individual to perform at maximum capacity. Identifying both the optimal wavelength for a given task and the minimum luminance needed for adequate contrast—balanced with minimizing risk of enemy detection from illumination—will result in acceptable, if not maximal, visual performance under tactical conditions.

Applied Visual Optics and Night Vision Concerns for SOFMED

The human eye is most sensitive to green light (555nm). Visual acuity is a function of light and contrast, with contrast being dependent on both color and texture (see earlier equation). More Special Operations occur at night, with a dependence on night vision devices a critical variable for success. The best vision possible with current generation NVG is 20/25—a resolution of telephone/cable *wires*. Without NVG, this drops to 20/200, and even this is with 25%–50% illumination and high-contrast backgrounds. Worst case vision with NVG occurs under no illumination with full overcast, no contrast, and no cultural lighting resulting in 20/70 acuity—the Operator cannot resolve telephone *poles*. A flight medic must be able to see his patient and complete complex medical tasks while continuing to serve in the role of air crew by scanning outside the aircraft. Preservation of dark adaptation and maximizing NV are obviously critical to success.[2]

Complicating system design is the fact that light-emitting diodes (LEDs) are harder to see with an Aviator Night Vision Imaging System (ANVIS) ORNVG system versus incandescent sources. Advantages of LEDs include less weight and energy consumption along with minimal heat signature. The "minus blue" coating in the ANVIS objective lens filters out panel and cockpit lights (blue-green light, which is best NV compatible). Additionally, blue light at night induces myopia (near-sightedness), while red light preserves dark adaptation and rods are not red sensitive.[2]

Recent Literature Supporting the Importance of Rational Lighting System Design

Despite the increased training and use of intraosseus access, intravenous (IV) line placement will always have a significant role in casualty care. Comparison of IV line placement under NVG and low-level white light illumination (Fingerlight) showed a significant advantage with the Fingerlight.[3] Avoiding tactical compromise may be possible with low-level white light sources, and this should be rigorously compared with NVG and other visible hues and intensities of illumination.

IV line placement and endotracheal intubation performed under NVGs were studied with emergency physicians and paramedics.[4] Both skills were performed successfully, but the times were significantly longer in the NVG group compared with daytime ambient illumination. Those added seconds to minutes are critical in the "platinum 10" minutes following initial injury. Three of the four preventable causes of death on the battlefield (compressible hemorrhage, airway compromise, and tension pneumothorax) are dependent on high visual acuity for proper treatment. Emphasis on developing appropriate lighting systems to facilitate these skills is obviously critical to improved outcomes.

While the eye is most sensitive to green light, depth perception was significantly impacted by green light compared with white, yellow, and red.[5] When designing lighting systems, we have many compromises that must still balance to promote successful human performance. These compromises are likely task-specific, promoting the concept of a multihue, tunable device.

Attempts to improve endotracheal intubation success under night vision conditions without compromising the tactical situation have led to development of a novel laryngoscope with an infrared filter. A 91.3% success rate[6] demonstrates the potential of tuning the illuminating wavelength to a given task–anatomy pairing. We plan to conduct additional studies to identify the ideal wavelengths of illumination for various tasks including arterial and venous vascular access, among other skills.

Clinical measures of stereopsis during NVG/ANVIS use are influenced by a learning curve.[7] It is reasonable that the performance of complex combat medic task using night vision devices would be similarly influenced by a learning curve. Providers should have adequate opportunity to train medical skills with these devices prior to deployment.

The civilian surgical suite is arguably one of the most controlled professional environments. A recent report[8] measured the distraction to the surgical team caused by lighting systems. Every 7.5 minutes, a lighting action took place. The needs driving these actions included improving wound illumination, changing the level of illumination, reducing shadows, and attempting to increase deep wound illumination. We can extrapolate these findings to the challenges faced by SOFMED providers when working in the dark, on complex casualties, while receiving incoming enemy fire.

Early in Operation Enduring Freedom, Army Special Forces medics (18D) identified needs for further predeployment training to match their increased medical responsibilities.[9] This need supported the premise of this survey, which was to ask the end-user what he needs based on experience and perceptions of success or failure.

A pilot study[10] suggests that fatigue may influence color perception in color-deficient (protanope) individuals. As SOF are color-normal, this effect may not be relevant but is an intriguing concept worthy of further investigation. Per AR 40-501 (14 December 2007), color vision is considered normal if the applicant for initial selection for Airborne, Ranger, and Special Forces Training passes the PIP set or FALANT test. The applicant may fail these tests and still be able to proceed with training if they are "able to identify red and/or vivid green as projected by the Ophthalmological Projector or the Stereoscope, Vision Testing (SVT)." We currently do not have data on how many SOFMED providers fit the above categories, but it is an area deserving further investigation.

Limitations of This Study

First, it must be stressed that this is essentially an anecdotal report with final quality of data driven by the desire of the individual respondent to participate. As with any survey, obligatory participation is not possible, especially in the context of the current operational tempo. We did not attempt to communicate with all SOFMED personnel via e-mail directly; rather, we chose a public posting on a commonly visited site available to the community. Therefore, a certain bias exists in the responses toward those who have active and/or strong feelings on the topic; they had to take the active step to go to the website and complete the survey. However, we do not feel this is a negative, and we were satisfied with 74 surveys completed in the access period for this publication. We chose to limit the survey to 10 questions with basic answer choices. Past experience shows that the more detailed the question and answer matrix, the less likely respondents may be to complete the survey accurately, if at all. Our findings support our own personal observations based on experience and discussions with seasoned

Operators. The intent was to provide an initial report designed to support further discussion and study. We look forward to feedback from our readers.

Proposed Ideal System for SOFMED

In summary, an ideal lighting system may require a blended versus single illumination wavelength (hues), perhaps with tunable wavelengths to suit tasks. The light source must be selected by minimizing limitations (LEDs are less compatible with NVG, for example). An NVG/ANVIS compatibility is an operational reality and must be optimized, especially for aviation applications. Weight should be minimal yet battery life must be exceptional. The ability to recharge via a solar roll or to transfer power from other devices via USB would be ideal. Perhaps most importantly, providers should have the ability to train and assess new systems—while under development—under tactical conditions simulating what is expected in current theaters of operation.

Conclusion

The ideal tactical lighting system for SOFMED applications remains elusive as evidenced by the number of approved commercially available units. While a given device must meet standards for safety and performance per U.S. Army and Aviation evaluation guidelines, there remains no regulation governing the efficacy of basic parameters. These include illumination intensity and hue, maintenance of contrast sensitivity, battery life, NVG/dark adaptation compatibility, and suitability for the given tactical task and setting. The results of this survey clearly show that casualty outcomes are directly impacted—both negatively and positively—by the lighting system employed. Ongoing studies by our team will define ideal lighting systems for the highly demanding and varied settings of SOFMED Operators to both minimize risk and to promote the best outcomes as deserved by our fighting force.

Disclaimer

The opinions and assertions contained in this report are those solely of the authors and not intended to be interpreted as official or reflecting the views of the Department of the Army, Army Reserves, Colorado National Guard, or the Department of Defense.

Disclosure

The authors have nothing to disclose.

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