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ACFASP Scientific Report: Lightning Safety for Indoor Swimming Pools

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Question to Be Addressed

What scientific evidence supports aquatic lightning safety practices?

Corollary Question

What scientific evidence exists to support either closing or keeping open indoor pools and aquatic facilities during thunderstorms?

Introduction/Overview

Estimates in the literature suggest somewhere between 300 and 1000 persons are struck by lightning annually in the U.S. These strikes result in 60-100 verified annual fatalities with up to 10 times that number who may suffer non-fatal injuries. Lightning is the second most common weather-related cause of fatalities (behind flooding) in the U.S. annually (Holle, Lopez, & Zimmermann, 1999).

Literature related to lightning safety practices is reasonably abundant, albeit largely based on expert opinion and commonsense. Few robust scientific studies exist upon which lightning safety recommendations are based. Many of the recommendations and guidelines (e.g., National Oceanographic and Atmospheric Agency; National Weather Service) appear to be traceable back to a few common sources including the National Lightning Safety Institute, a non-profit agency, and the Lightning Safety Group, an interest group meeting in conjunction with the American Meteorological Society. Despite the lack of scientific studies, the recommendations from these expert agencies are remarkably similar and consonant.

With respect to the corollary question, what scientific evidence exists to support either closing or keeping open indoor pools and aquatic facilities during thunderstorms, surprisingly, there appear to be no studies upon which several agency policies are based beyond logic and risk management principles. The lack of research makes resolution of this particular issue difficult to impossible at this time.

Because of the inherent danger of studying lightning empirically, traditional empirical research studies do not exist nor is it desirable to carry them out for the purpose of studying lightning. Hence, this review relies heavily on existing expert

opinion and anecdotal evidence while creative methods (e.g., naturalistic, observational, or survey studies) for studying the potential impact of lightning on water, specifically indoor pools and other aquatic facilities can be identified and conducted. There are several new laboratory-based approaches (e.g., using lasers) that may allow future simulation studies of lightning. Currently, they are too experimental to have reached the general scientific literature.

Because of the potential seriousness of lightning-related accidents and deaths, the need exists to examine the current recommendations employed by different agencies and organizations and to support or refute such recommendations with scientific evidence, where possible. The literature actually recognizes the gulf between scientific knowledge and typical recommendations (Holle et al., 1999). In particular, the common and widely cited recommendation directing persons to avoid all contact with sources of water (e.g., open bodies, pools, showers, bathtubs) during electrical storms is one corollary focus of this review.

Scientific Expertise on Lightning Safety Issues

It appears the two major U.S. public agencies with scientific expertise related to lightning safety are the American Meteorological Society (AMS) and the National Oceanic and Atmospheric Administration (NOAA) (to which the National Weather Service (NWS) reports in its mission to produce official US weather, marine, fire and aviation forecasts, warnings, meteorological products, climate forecasts and information about meteorology). Another frequently cited "non-profit," albeit proprietary, group is called the National Lightning Safety Institute (NLSI). Of these agencies and organizations, AMS is actually the primary scientific society which has produced several important lightning safety statements (AMS Council, 2002, Roeder, 2002). In fact, personal communications with personnel from NOAA and NWS suggest that those two agencies primarily rely upon the expertise of AMS and NLSI to a great degree in crafting their lightning safety recommendations.

Two other related agencies who are active in electrical and lightning safety issues and recommendations are the Electrical Safety Foundation International (ESFI) and the Lightning Protection Institute (LPI). Along with the NOAA's National Weather Service, these agencies promote an annual Lightning Safety Awareness Week, usually in mid-June. During the past year (2009), NWS adopted the slogan, "When Thunder Roars, Go Indoors!" as part of their public service campaign.

Lighting Safety Recommendations

As mentioned in the introduction, lightning safety recommendations across agencies (e.g., AMS Council, 2002; American Red Cross tear sheet; ASSE, 2005) are remarkably consistent, despite the lack of any definitive scientific research supporting them. Obviously, because of the potentially severe consequences of being struck by lightning (e.g., death, permanent neurologic impairment, severe burns), this is an area that neither lends itself to traditional empirical research nor necessarily requires it.

One area of potential conflict related to the indoor swimming pool issue is the recommendation of avoiding all sources of water or plumbing, especially indoors.

This is the consistent recommendation from all agencies. It appears to be based primarily upon anecdotal reports of lightning injuries to persons in bathtubs or in contact with plumbing during thunderstorms. No statistical evidence is ever presented. It is the primary recommendation upon which the proponents of closing indoor swimming pools rely in their arguments. Since swimming pools are large bodies of water, connected to plumbing and electrical sources (e.g., filters, drains, heaters), the logic is that, despite required ground-fault systems, the enormity and chaotic nature of electrical charges from lightning (i.e., 50,000 volts), ground fault systems are inherently inadequate. The opponents of closing swimming pools counter with the statistic that no reported deaths have ever occurred in indoor swimming pools. It is a dichotomous argument with unlikely resolution.

Selected References

American Society of Safety Engineers (2005). ESFI, LPI urge awareness of lightning safety, *Professional Safety*, p. 48-49.

AMS Council. (2002) Lightning safety awareness, *Bulletin of the American Meteorological Society, 83*, 260-261.

American Red Cross (2009). Thunderstorms tear sheet. Washington, D.C.: author.

Andrews, C.J., Cooper, M.A., Darveniza, M., & Mackerras, D. (1992). Lightning injuries: Electrical, medical, and legal aspects. City: CRC Press.

Bennett, B. L. (1997). A model lightning safety policy for athletics. *Journal of Athletic Training*, *32*, 251-253.

Bennett, B.L., Holle, R.L., & Lopez, R.E. (1997). Lightning safety. In M.V. Earle (Ed.), *1998-99 NCAA Sports Medicine Handbook* (11th Ed.) (pp. 12-14), Indianapolis: National College Athletic Association.

Griffith, T., & Griffiths, M. (2008). When lightning strikes. *Aquatics International*,

Holle, R.L., Lopez, R.E., & Zimmermann, C. (1999). Updated recommendation for lightning safety-1998, *Bulletin of the American Meteorology Society*, 2035-2041.

Kithil, R. (2008). Lightning and indoor pools: A reply to Aquatics Resources eSplash Newsletter 17 Nov 2008. Unpublished paper by National Lightning Safety Institute, retrieved from http://www.lightningsafety.com/ on 13 June 2009.

Kithil, R., & Johnston, K. (2008, November). Lightning and aquatics safety: A cautionary perspective for indoor pools. Unpublished paper by National Lightning Safety Institute, retrieved from http://www.lightningsafety.com/ on 13 June 2009.

Roeder, W.P. et al. (2002). *Updated recommendation for lightning safety-2002*. Paper submitted to AMS Council, April, 2002.

Selected Websites

American Meteorological Society http://www.ametsoc.org/ **Lightning Safety Awareness**—(Adopted by the Council 29 April 2002), Bull. Amer. Met. Soc., 84, 260—261 http://www.ametsoc.org/policy/lightningpolicy_2002.html.

National Weather Service.

http://www.lightningsafety.noaa.gov/

http://www.noaanews.noaa.gov/stories2009/20090617_lightning.html

http://www.lightningsafety.noaa.gov/indoors.htm

http://www.lightningsafety.noaa.gov/science.htm

How stuff works. http://www.howstuffworks.com/lightning.htm

Review Process and Literature Search Performed

An on-line literature search using EBSCO databases was conducted through the OhioLink on-line library network. Search terms included "lightning," "lightning safety," "lightning and swimming pools," and "lightning and indoor swimming pools." The term "lightning safety" yielded 241 references, about 20% of which were available in full text and appropriate to this review. The search yielded only 4 references to "lightning and swimming pools" and no references for "lightning and indoor swimming pools."

In addition, websites for the American Meteorological Society, the National Oceanic and Atmospheric Administration (NOAA), the National Weather Service (NWS), the National Lightning Safety Institute, Electrical Safety Foundation International, and the Lightning Protection Institute were examined and searched for appropriate materials and information.

Current American Red Cross materials (e.g., thunderstorm tear sheet) also were reviewed.

Summary of Key Articles/Literature Found and Level of Evidence

Author(s)	Full Citation	Summary of Article	Level of Evidence
ASSE	American Society of Safety Engineers (2005). ESFI, LPI urge awareness of lightning safety, *Professional Safety*, p. 48-49.	Short professional article addressed the danger associated with lightning and providing a series of recommendations for lightning safety practices	6
AMS Council	AMS Council. (2002) Lightning safety awareness, *Bulletin of the American Meteorological Society, 83*, 260-261.	Official statement including lightning safety recommendations from the American Meteorological Society.	5
Andrews, C.J. *et al.*	Andrews, C.J., Cooper, M.A., Darveniza, M., & Mackerras, D. (1992). Lightning injuries: Electrical, medical, and legal aspects. City: CRC Press.	This text provides a somewhat dated overview of lightning injuries prior to 1990 from electrical, medical, and legal perspectives.	6
	Bennett, B. L. (1997). A model lightning safety policy for athletics. *Journal of Athletic Training*, *32*, 251-253.	This is a recommendation for model safety practices associated with preventing lightning injuries in outdoor sports.	6
	Bennett, B.L., Holle, R.L., & Lopez, R.E. (1997). Lightning safety. In M.V. Earle (Ed.), *1998-99 NCAA Sports Medicine Handbook* (11th Ed.) (pp. 12-14), Indianapolis: National College Athletic Association.	These pages from the NCAA guidebook are focused on similar recommendations for athletics to those contained in the Bennett (1997) paper.	5

Author(s)	Full Citation	Summary of Article	Level of Evidence
	Griffith, T., & Griffiths, M. (2008, November/December). When lightning strikes. *Aquatics International*, 19-21.	This paper from Aquatics International stirred up the controversy about whether or not to vacate indoor swimming pools during thunderstorms. The authors use logical arguments against a policy of closing indoor pools during thunderstorms.	7
	Holle, R.L., Lopez, R.E., & Zimmermann, C. (1999). Updated recommendation for lightning safety-1998, *Bulletin of the American Meteorology Society*, 2035-2041.	This statement pre-dates the AMS Council statement (2002). Recommendations are very similar in content.	5
	Kithil, R. (2008). Lightning and indoor pools: A reply to Aquatics Resources eSplash Newsletter 17 Nov 2008. Unpublished paper by National Lightning Safety Institute, retrieved from http://www.lightningsafety.com/ on 13 June 2009.	This paper appeared on the NLSI website in response to the Griffith & Griffiths (2008) paper.	7
	Kithil, R., & Johnston, K. (2008, November). Lightning and aquatics safety: A cautionary perspective for indoor pools. Unpublished paper by National Lightning Safety Institute, retrieved from http://www.lightningsafety.com/ on 13 June 2009.	This paper from the NLSI website was likely the impetus for the Griffith & Griffiths (2008) paper. It lays out a logical rational for closing indoor swimming pools during thunderstorms mainly on liability grounds, not directly safety.	7
	Roeder, W.P. et al. (2002). *Updated recommendation for lightning safety-2002*. Paper submitted to AMS Council, April, 2002.	This paper, authored by 12 of the leading experts in lightning safety provides an excellent overview of the physics and climatology of lightning, demographic information, and recommendations. It served as the basis for the AMS Council statement (2002).	5

Level of Evidence	Definitions (see manuscript for full details)
Level 1a	Population based studies, randomized prospective studies or meta-analyses of multiple studies with substantial effects
Level 1b	Large non-population based epidemiological studies or randomized prospective studies with smaller or less significant effects
Level 2a	Prospective, controlled, non-randomized, cohort or case-control studies
Level 2b	Historic, non-randomized, cohort or case-control studies
Level 2c	Case series: convenience sample epidemiological studies
Level 3a	Large observational studies
Level 3b	Smaller observational studies
Level 4	Animal studies or mechanical model studies
Level 5	Peer-reviewed, state of the art articles, review articles, organizational statements or guidelines, editorials, or consensus statements
Level 6	Non-peer reviewed published opinions, such as textbook statements, official organizational publications, guidelines and policy statements which are not peer reviewed and consensus statements
Level 7	Rational conjecture (common sense); common practices accepted before evidence-based guidelines
Level 1-6E	Extrapolations from existing data collected for other purposes, theoretical analyses which are on-point with question being asked. Modifier E applied because extrapolated but ranked based on type of study.

Scientific Foundation

Summary

The existing lightning safety recommendations and practices primarily depend upon logical conjecture and expert opinion. There is a large gap between the scientific evidence and these recommendations. Due to the potentially severe consequences of being struck by lightning, it is logical from safety, ethical, and legal perspectives to abide by the existing recommendations because there is no evidence to suggest that they endanger persons. At the same time, more scientific studies need to be conducted in order to provide a basis for the recommendations.

At particular issue in this review is the role of water in conducting lightning and endangering humans, especially with respect to whether indoor swimming pools should be closed during thunderstorms or not. Despite the absence of research and reliance upon anecdotal reports and expert opinion, a similar conclusion to the general lightning safety recommendations can be reached: due to potential safety, ethical, and legal reasons, it is best to follow the conservative option of removing bathers from all aquatic facilities (regardless of outdoors or indoors) during thunderstorms, following the AMS (2002) 30-30 recommendation (i.e., take cover when the time between lightning flash and thunder is 30 seconds or less and remain under cover until 30 minutes after the last lightning is seen or thunder heard; avoiding plumbing and electrical circuits), until such time as research is available to the contrary.

Recommendations and Strength (Using Table Below)

Standards:

Guidelines:

Options:

The general lightning safety recommendations (e.g., 30 second-30 minute rule; avoiding plumbing or electrical circuits), are supported mainly by expert opinions (Class IV – No convincing scientific evidence available but supported by rational conjecture, expert opinion and/or non peer-reviewed publications). It makes sense to err on the side of safety and ask patrons of both indoor and outdoor to leave the water immediately and stay in an identified safe area free from water, plumbing, or electrical circuits until 30 minutes after the last lightning sighting or thunder sound.

Class	Description	Implication	Level of Evidence
I	Convincingly justifiable on scientific evidence alone.	Usually supports Standard	One or more Level 1 studies are present (with rare exceptions). Study results consistently positive and compelling
II	Reasonably justifiable by scientific evidence and strongly supported by expert opinion.	Usually supports Guideline but if volume of evidence is great enough and support from expert opinions is clear may support standard	Most evidence is supportive of guideline. Level 1 studies are absent, or inconsistent, or lack power. Generally higher levels of evidence. Results are consistently supportive of guideline.
III	Adequate scientific evidence is lacking but widely supported by available data and expert opinion. Based on	Usually supports Option.	Generally lower or intermediate levels of evidence. Generally, but not consistently results are supportive of opinion.
IV	No convincing scientific evidence available but supported by rational conjecture, expert opinion and/or non peer-reviewed publications	Usually does not support standard, guideline, or option. Statement may still me made which presents what data and opinion exists. In some cases and in conjunction with rational conjecture may support option.	Minimal evidence is available. Studies may be in progress. Results inconsistent, or contradictory.