Extremity Tourniquet Training at High Seas

Carlos Yánez (carlosyb1@gmail.com)
Servicio Aragones de Salud https://orcid.org/0000-0003-4998-5915
Marcelo Ribeiro
Catholic University of Sao Paulo PUC-Sorocaba and Hospital Moriah
Mansoor Khan
Brighton and Sussex University Hospitals
Teófilo Lorente
Servicio Aragonés de Salud: Servicio Aragones de Salud
Esther Asensio
General Hospital of the Defense of Zaragoza
José Antonio López
Spanish Armada
Isabel Martínez
Spanish Armada
Juan L Blas
Servicio Aragones de Salud
Antonio Güemes
Servicio Aragones de Salud

Research

Keywords: Hemorrhage, Tourniquets, Education & Training, Ocean, Seas

Posted Date: December 10th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-122867/v1

Abstract

Background

Future navy officers require unique training for emergency medical response in the isolated maritime environment. The authors issued a workshop on injury classification and extremity bleeding control, using four different commercial extremity tourniquets onboard a training sail ship. The purpose was to assess participants' perceptions of this educational experience and evaluate application simplicity while navigating on high seas.

Methods

A descriptive observational study was conducted as part of a workshop issued to volunteer sailors. A post-workshop survey collected participants` perceptions about the workshops' content usefulness and adequacy, tourniquet safety, application simplicity in high seas, and device preference. The studied variables were measured on a one-to-ten Likert scale, while tourniquet preference by frequency count. Frequencies and percentages were calculated for the studied variables, and application simplicity means compared using the ANOVA test ($p<0,05$).

Results

Fifty-one Spanish training naval officers, aged from 20-21, perceived workshop content usefulness, adequacy, and safety level in high sea use at 8.6/10, 8.7/10, and 7.5/10, respectively. As for application simplicity, CAT and SAM-XT were rated equally with a mean of 8.5, followed by SWAT (7.9) and RATS (6.9). The only statistical difference found was for the RATS ($p<0.01$). Windlass models were preferred by 94%, and elastic tourniquets by 6%.

Conclusions

The training sail ship extremity bleeding control workshop was perceived as useful and its content adequate by the participating midshipmen. Windlass tourniquet types were regarded as easier to apply than elastics models and were the preferred model by nine out of every ten participants.

Background

Training sail ships are employed by several navies worldwide as navigating classrooms where future officers receive training in navigation techniques and seafaring procedures. The Spanish Navy has the four-masted "Juan Sebastian de Elcano" (JSE) that has sailed over two million nautical miles [1]. The ship is the campus for the semester at sea program of the fourth academic year in the Naval Academy syllabus. The studies onboard typically include navigation, meteorology, geography, naval maneuvers, naval signaling, electronic warfare, and naval weaponry. In 2019 the XCI voyage of the JSE included an innovative extracurricular workshop during high sea navigation. For the first time, extremity bleeding control and tourniquet assessment training were scheduled as part of the onboard educational program.

Hemorrhage is the leading cause of preventable death in both military and civilian trauma. Early application of extremity tourniquets at the point of injury is currently accepted as the standard treatment for life-threatening extremity hemorrhage [2-4]. The classic Pre-Hospital Emergency Care (PHEM) paradigm changed from airway-breathing-circulation (ABC) to Military-PHEM (M-PHEC) that addresses first catastrophic hemorrhage, before airway, breathing or circulation (<C> ABC) [5]. The change of priorities and the timing of extremity tourniquet application on the field before the onset of shock is associated with improved survival [6]. This innovative concept introduced by the military is currently also advocated in civilian practice [7]. Most of the published reports on tourniquet use focus on military experience gained from its application by ground troops and field hospitals [8-10]. However, this essential lifesaving technique employed by the Medical Emergency Response Teams (MERT) is useful not only for ground troops but also in austere and isolated practice environments [11]. Naval operations and seafaring require unique emergency medical response training due to the isolated setting, the turbulence encountered in high sea states, motion sickness, restricted storage space, limited resources, and distance from sophisticated medical facilities. Specialized units of the Royal Navy have developed specifically trained teams for M-PHEC in the maritime environment [11-14]. These Primary Retrieval Teams (PRT) provide M-PHEC for a maritime environment with limited equipment. One of the PRT teams' crucial skills is hemorrhage control with extremity tourniquets and hemostatic agents. This type of tourniquet bleeding control skills can be integrated to the education received by future navy officers during their semester at sea training, and the current syllabus does not cover such essential learning. Training gaps for military naval surgeons isolated at sea have been identified before, considering the unique educational needs and working conditions afloat [15]. However, to fill the training gap of basic PHMC principles among future navy officers, updated concepts of tourniquet application and limb pressure dynamics should be explained and not limit the training only to a tourniquet application technique. Current understanding of how extremity tourniquets work has changed from a mechanistic to a probabilistic approach. Tourniquet occlusive pressure decreases over time, requiring frequent reassessment on the field [16]. Today the tetrad concept of a user, patient, intervention, and situation explains how tourniquets applied on the field effectively can become loose over time [6]. The educational boards should incorporate the new understanding of tourniquet dynamics into tourniquet application workshops in all military branches.

Preparation of future navy officers during the semester at sea offers a unique opportunity to impart these current M-PHEC principles to inexperienced midshipmen during open-sea navigation. High sea conditions have been simulated for studying surgical teams' performance afloat [17]. However, to our knowledge, no previous studies have reported extremity tourniquet application workshops aboard naval training sail ships in high seas. Navy training sail ships offer realistic conditions on-site for the schooling of tourniquet application skills in a maritime environment. To enhance future officers' education aboard the JSE, the researchers conceived an extremity bleeding control and tourniquet training workshop during a transoceanic voyage.

This study aimed to assess the midshipmen's perception of the workshop's usefulness, content adequacy, perception of onboard tourniquet application safety, and overall satisfaction with the activity. Additionally, the study attempted to evaluate which type of tourniquet mechanism, windlass, or elastic would be easier to apply by inexperienced users in a maritime environment navigating high seas, and which of the tested models would be preferred. We hypothesized that despite the innovativeness of the activity and the obstacles of navigating with high sea conditions, the workshop would be well received by the young midshipmen onboard the JSE and would serve as a realistic training experience for future naval officers.

Methods

A descriptive observational study was conducted during the 2019 voyage aboard the Spanish Armada's Juan Sebastian de Elcano training sail ship. **(Figure.1)** The study was conducted with the Educational Committee's approval and authorized by Juan Sebastian de Elcano's commanding officer. It exempted ethical approval since all the study activities were part of the sailors onboard training program and did not involve any human or animal experimental activities. The authors conceived a one-day workshop issued in the middle of the South Atlantic Ocean after 30 days of navigation in a high sea state. The workshop was structured into two activities. The first focused on the theoretical content and consisted of two 1-hour lectures addressing the physiology of trauma hemorrhage, extremity bleeding control management techniques, updated principles of tourniquet dynamics, and indications for proper extremity tourniquet use. The briefing included tourniquet pre-positioning, upper and lower extremity tourniquet positioning, proper securing technique for each of the devices tested, and effectiveness assessment techniques. The second activity consisted of a post-lecture two-hour hands-on workshop performed in a fully equipped sailing uniform with offshore waterproof overgarments. All the participants had the opportunity to perform self-application and buddy-application techniques on upper and lower extremity using four different commercial extremity tourniquets, two windlass types, and two elastic models. The tourniquets selected for the study were the windlass models, C•A•T Resources, LLC, Combat Application Tourniquet® Gen-7 (CAT), and the SAM Medical®, SAM-Extremity Tourniquet (SAM-XT). The elastic models employed were the HH Med-Corp, Stretch, Wrap, and Tuck Tourniquet (SWAT™), and the RATS- Rapid Medical, Rapid Application Tourniquet System Gen 1 (RATS®). The ship's physician, a seasoned surgeon with ample tourniquet use experience, delivered all the lectures and briefings. Two senior officers assisted him during the hands-on activity, supervising tourniquet application technique and assessing application effectiveness by palpating radial pulse on the upper extremity and by inspection when used in the lower extremity.

All the workshop participants were healthy midshipmen who completed the standard fourth year semester at sea of the Spanish naval academy curricular program. None of the participants had prior experience with tourniquet application during oceanic voyages and had not participated in previous specific tourniquet workshops during navigation. Participation in the study was voluntary and excluded those performing essential navigation tasks. A post-workshop anonymous structured survey collected data in four categories. The first obtained participants demographic data, the second queried attendees' perceptions regarding the workshop's usefulness, content adequacy, perception of onboard tourniquet application safety, and overall satisfaction with the activity. The third category assessed participants' opinions concerning the simplicity of self and buddy application for each of the models tested and the last queried device preference. Descriptive statistics were applied to the demographical data, and the rest of the assessed variables were measured on a Likert one-to-ten linear scale. Ten represented highly adequate or useful, simplest or safest, and one, less adequate or useful, the least simple or least safe, depending on the variable queried. Tourniquet preference was measured by frequency count, with only one device to select as the preferred. Likert scale means for the perception of application simplicity during navigation for each tourniquet was compared using the ANOVA test with repeated measure; $p < 0.05$ was considered statistically significant.

Results

Fifty-one individuals (*n* = 51) participated in the study, 8 (16%) females, and 43 (84%) males, aged between 20 and 21. The study was conducted during the six-month XCI voyage of the JSE that departed from Cadiz, Spain, on the 13th of January of 2019. The workshop was issued in the middle of the South Atlantic Ocean in a high sea state 30 days after the departure from Santa Cruz, Tenerife while navigating to San Juan, Puerto Rico. **(Figure. 2)** The reported mean value for workshop usefulness among participants was 8.6 and 8.7 for content adequacy, while the workshop's overall satisfaction was given a mean rating of 9.3. The opinion regarding onboard tourniquet use safety was rated with a mean of 7.5. Assessment of the four devices' application simplicity during navigation in high seas showed that the tourniquets with a windlass mechanism (CAT and SAM-XT) were considered simpler to use, both with a mean value of 8.5. Both elastic tourniquet models were ranked lower than the windlass models (SWAT, 7.9; RATS, 6.9). **(Figure. 3)** However, a statistical difference was only found for the RATS model ($p<0.01$), which ranked the lowest. **(Figure. 4)** Regarding tourniquet preference, of the four models tested, the CAT was selected as the preferred tourniquet by 38 participants (74%), followed by the SAM-XT 10 (20%), SWAT 2 (4%), and RATS 1 (2%). When comparing device preference based on the device's mechanism, the windlass models (CAT and SAM-XT) were preferred by 94%, and only 6% favored the elastic models (SWAT and RATS). **(Figure. 5)**

Discussion

This descriptive observational study of the implementation of an extremity bleeding control and tourniquet application workshop among inexperienced midshipmen of the JSE during navigation on high seas demonstrates the educational value of these training exercises as part of their activities. The highly ranked perception of usefulness (8.6) and content adequacy (8.7) of ET training during high sea navigation corroborate the convenience of incorporating these activities as a part of the academic program aboard training sail ships. Additionally, the high level of overall satisfaction (9.3) declared during the activity stimulates teamwork and partnership, two essential aspects of midshipmen training during distant journeys. However, when asked for the perception of the safety of tourniquet use onboard, the participants' response reveals concerns of causing ischemic damage to limbs with tourniquet use and apprehension regarding the safety of these devices in isolated maritime environments. These worries could be understandable considering the remote location and the limited availability for advanced surgical care. It is worth commenting that tourniquet application both in the field and in isolated scenarios is a temporary bleeding control measure that, as soon as possible, should be re-evaluated and possibly replaced with a hemostatic dressing or other methods of definitive bleeding control.

Even though there was no direct measure of the teaching success of the activity onboard the sailing ship, the authors consider that the educational value of performing hands-on supervised training with four different commercial tourniquets while navigation in high sea conditions is precious. The participants had no prior experience using ET during navigation, so it served as an initial pedagogic experience that should be enhanced in future training. Martinez et al. describe a useful performance score for ET training programs that includes a scale with four categories: effectiveness, total placement time, tourniquet pre-positioning, and tourniquet preparation [18]. However, his score is described to measure the impact of a refresher course on deployed soldiers with prior ET training in a non-maritime environment. The conditions in which our study was developed made its application impracticable. Nonetheless, it does highlight the benefit of progressive learning and performing knowledge refreshing training sessions on newly deployed military personnel. These findings are similar to those reported by Kragh et al. advocating for basic training early during the soldiers' formation and later in-depth retraining with refresher training before any deployment [6]. Our workshop attempted to issue basic training to the future naval officer without prior ET application experience during navigation, creating a foundation for future and progressive skill acquirement. This gradual learning of basic PHEM principles by future navy officers during the semester at sea activities should be reproduced by other naval sail ships.

Several countries have training sail ships in their Navy's (U.S Coast Guard the "USCG Eagle," German Navy the "Gorch Fock," Royal Australian Navy the "Young Endeavour," Italian Navy the "Americo Vespucci," Indian Navy the "INS Tarangini," Bolivarian Navy of Venezuela the" Simon Bolivar," Japanese Navy the "Kaiwo Maru," Peruvian Navy the "BAP Union," and Polish Navy the "Dar Młodzieży," Chilean Navy "Esmeralda"). However, this type of workshop has not been previously reported in any of them to our knowledge. Naval training sail ships offer future navy officers a realistic scenario for training maritime PHEC principles, and ET application workshops are an essential part of such training. This specific bleeding control training better prepares them for potential injuries during high sea navigation in an isolated maritime environment, considering that the oceans are the largest wilderness areas on earth. Even during non-hostile training tours, sailing with adverse weather can cause serious injuries resulting from broken sail lines under tension, leading to soft tissue lacerations and severe extremity hemorrhage [19]. Future naval officers must also prepare themselves for potential maritime hostile activities exposing them to penetrating extremity trauma and blast injuries.

Training PHEC and ET applications while navigating high seas vary considerably with customary practice conditions of land troops. Constant and irregular vessel motion can unfavorably condition tourniquet application simplicity. Our study reported higher application ease for the windlass models in high sea conditions. There are few reports of extremity tourniquet application by naval units to which compare our results. Heldenberg et al. (2015) published their study evaluating three tourniquet types (CAT, Special Operations Force Tactical Tourniquet "SOFTT" and an improvised device) among 23 operators of the Israeli Naval Defense Forces [20]. Their findings regarding application simplicity were similar to ours, with CAT and SOFTT, both windlass type tourniquets graded as higher for simplicity of application. However, their study compared windlass ETs with an improvised elastic model; participants were experienced navy special forces operators, and their study was not performed during high sea navigation, so direct comparison of both study results is not adequate. Our results show that even without prior training, the JSE midshipmen considered the two windlass type tourniquets (CAT and SAM-XT) easier to apply than the elastic model in navigating conditions. Concerning device preference, again, the results favor the windlass mechanism commercial tourniquets for self-application and buddy-application in a maritime environment. The constant ship movement during high sea states different from the land application, and the simple windlass tourniquet securing system may have influenced participants' choice.

Limitations

Limitations of this study include the lack of participation of all the midshipmen aboard. The limited time dedicated to the hands-on practice and that the attendee's responses and preferences were based on personal perceptions. The lack of assessment of how different weather conditions and vessel movement affected the ease of tourniquet application. Furthermore, due to the study conditions, there was no direct measure of the teaching success. However, our workshop's participants' perceptions about its usefulness, content adequacy, overall satisfaction, and onboard tourniquet use safety suggest convenience. The workshop added valuable tourniquet application training in high sea conditions to future navy officers. Future research should be directed at developing maritime M-PHEC educational programs on other training sail ships and designing methods for evaluating such programs' teaching success. The researchers should also develop and test more tourniquet models and hemostatic agents specific to the unique maritime environment.

Conclusion

Extremity bleeding control workshop on the JSE training sail ship was perceived as useful and its content adequate by the participating future navy officers. Training sail ships provide realistic high sea conditions for maritime extremity tourniquet application training. The two windlass tourniquet models (CAT and SAM-XT) were regarded as equally easy to apply and simpler than the two elastic tourniquets tested (SWAT and RATS). The commercial windlass devices were preferred over elastic tourniquet models by nine out of every ten participants.

Abbreviations

JSE: Juan Sebastian de Elcano

PHEC: Pre-Hospital Emergency Care

M-PHEC: Military Pre-Hospital Emergency Care

MERT: Medical Emergency Response Teams

PRT: Primary Retrieval Teams

CAT: Combat Application Tourniquet

SAM-XT: SAM-Extremity Tourniquet

SWAT: Stretch Wrap and Tuck Tourniquet

RATS: Rapid Application Tourniquet System

SOFTT: Special Operations Force Tactical Tourniquet

Declarations

Acknowledgments: Our acknowledgment to the Spanish Armada for their support and approval for this study and the Juan Sebastian de Elcano crew members, particularly those who volunteered for the study. Our thanks to Mercedes Muñoz, information specialist, for assistance in the literature research; to Carlos Yánez Sr., PhD., for his revision; and to Ilaria Biondi, the medical illustrator.

Authors' contribution: All authors meet the authorship criteria for this manuscript as described below. CY, AG, and TL conceived the study. AG, EA, JAL, and IM performed the study onboard. The literature search was performed by CY, MR, MK, and JLB. The manuscript draft was written by CY, TL, and AG. The final manuscript revision was done by AG, MR, MK, TL, and JLB. All authors reviewed and approved the final manuscript.

Funding source: None

Availability of data and material: The data that support the findings of this study are not publicly available. However, data are available from the authors upon reasonable request and permission of the Spanish Armada and the Juan Sebastian de Elcano commanding officers.

Ethical standards:

The study was conducted with the Educational Committee's approval and the commanding officer of the Juan Sebastian de Elcano's approval. It exempted ethical approval due to the lack of human experimenting or animal testing. All the participants were informed of the study purposes and volunteered to participate in the study. All activities were part of the sailors onboard training program and did not involve any experimental activities.

Consent for publication: The submission does not include images that may identify the person.

Competing interest: Carlos Yánez Benítez, Marcelo A. F. Ribeiro Jr., Mansoor Khan, Teófilo Lorente, Esther Asensio, José Antonio López, Isabel Martínez, Juan L Blas, and Antonio Güemes have no competing interest to declare.

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Figures

Figure 1

Spanish' Armada "Juan Sebastian de Elcano" training sail ship hosted the tourniquet application and assessment workshop during the 2019 voyage.

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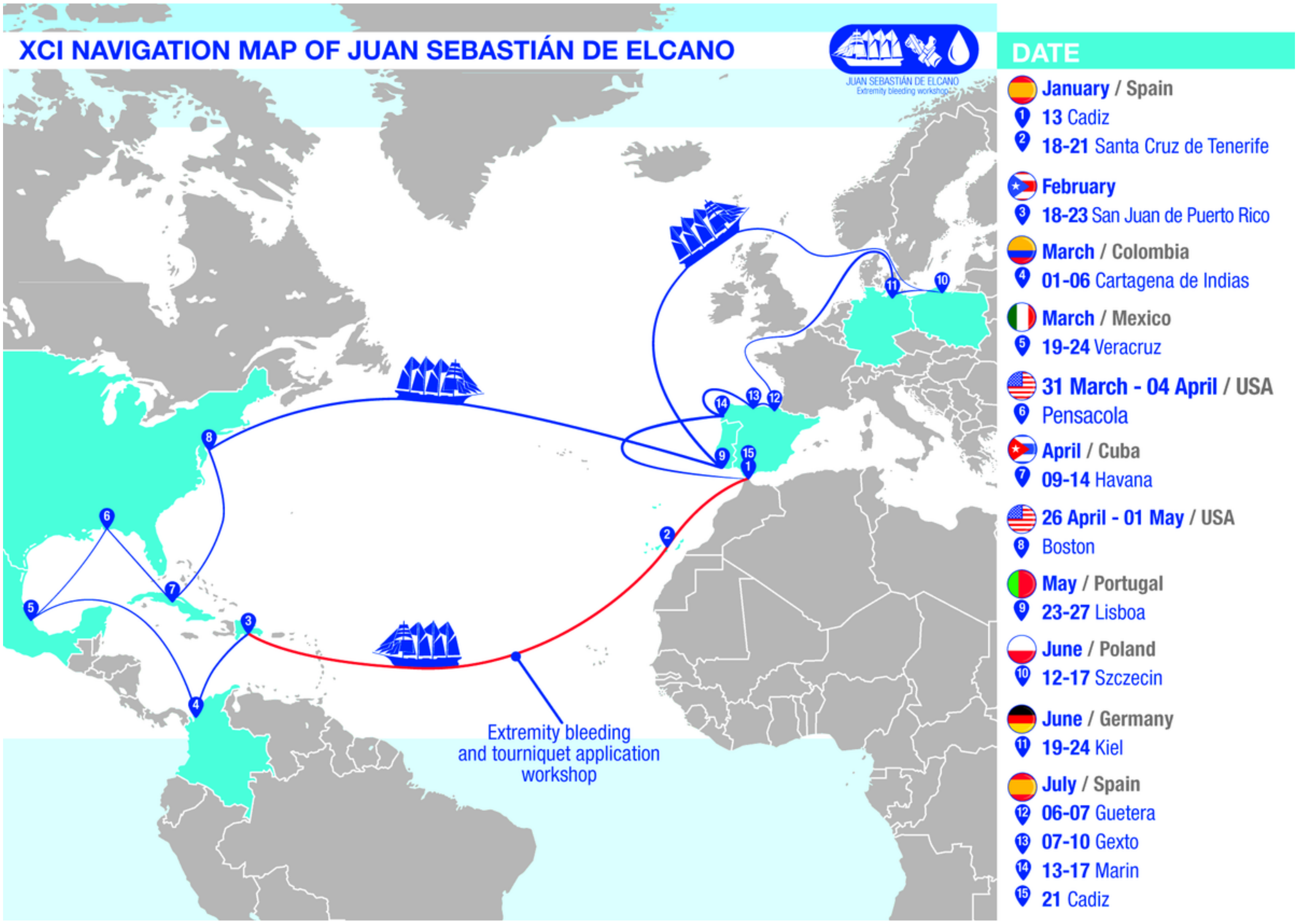
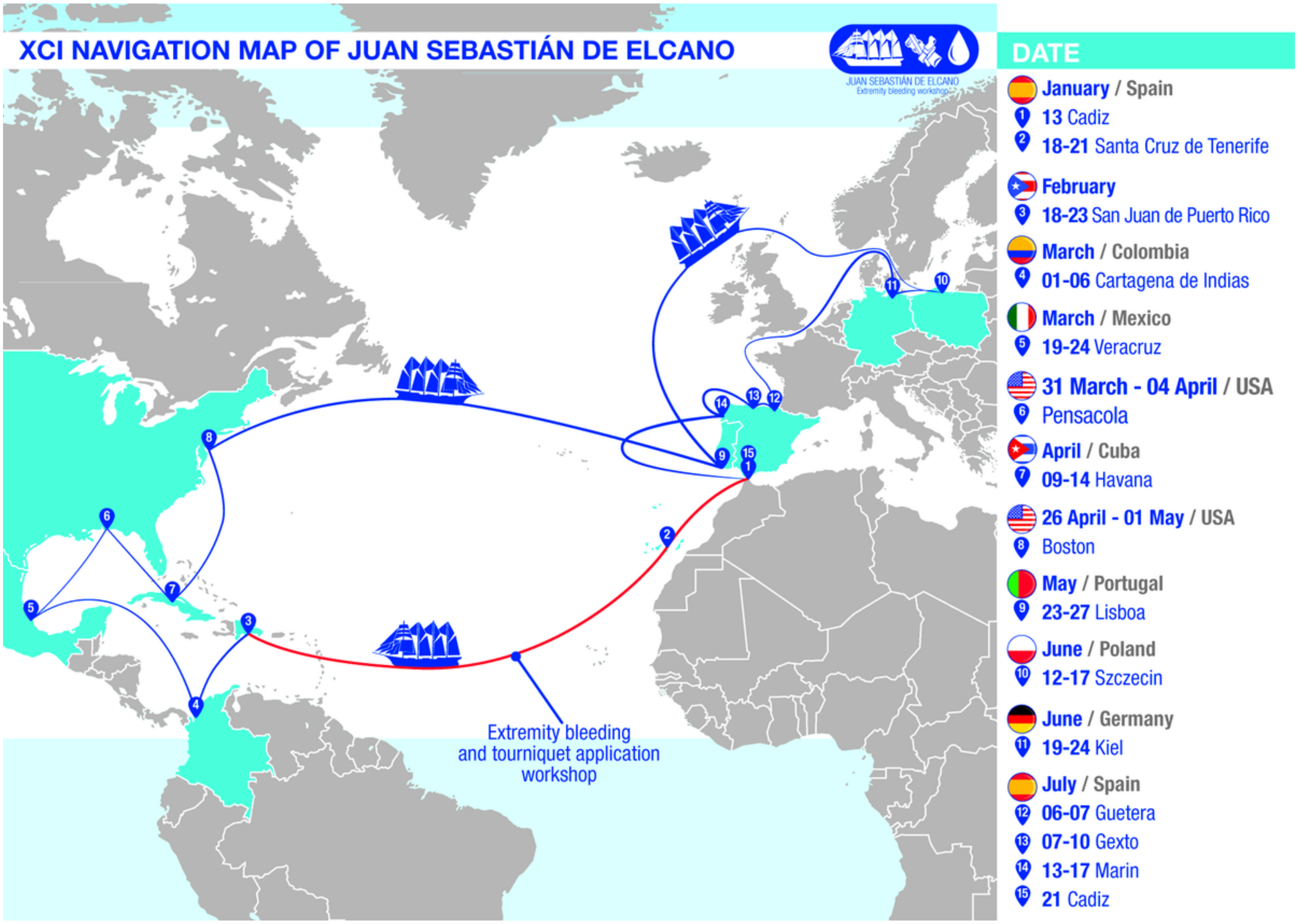


Figure 2

Navigation map of the Juan Sebastian de Elcano 2019 six-month voyage. The extremity tourniquet workshop was performed on high seas during the trip from Santa Cruz, Tenerife to San Juan, Puerto Rico, in the middle of the South Atlantic Ocean. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



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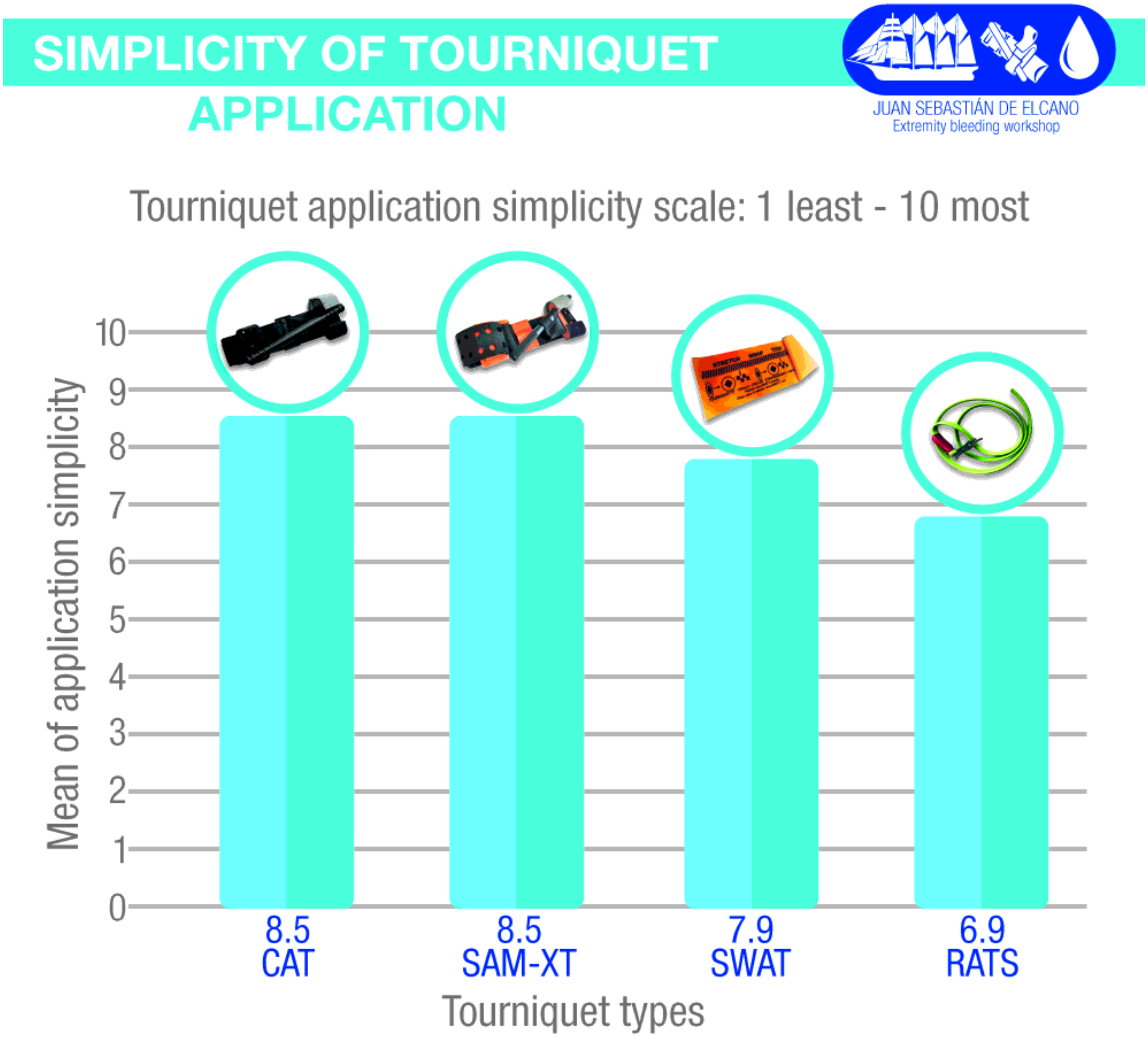
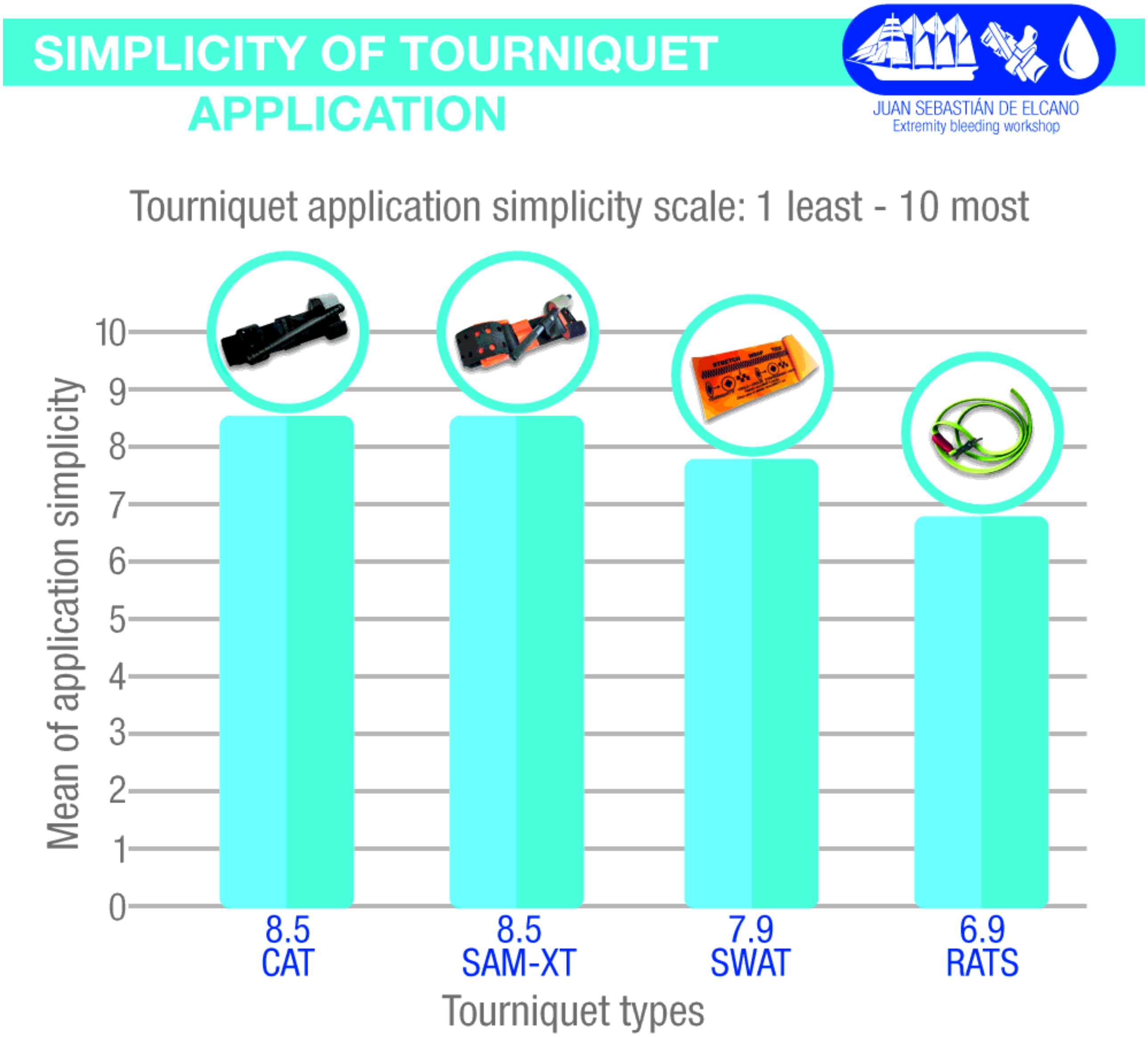


Figure 3

Mean of application simplicity for each extremity tourniquets employed during the JSE workshop during high sea navigation. (CAT 7-Combat application Tourniquet® Gen-7, SAM-XT Sam Application Tourniquet®, SWAT™ Stretch Wrap and Tuck Tourniquet, RATS® Rapid Application Tourniquet System).



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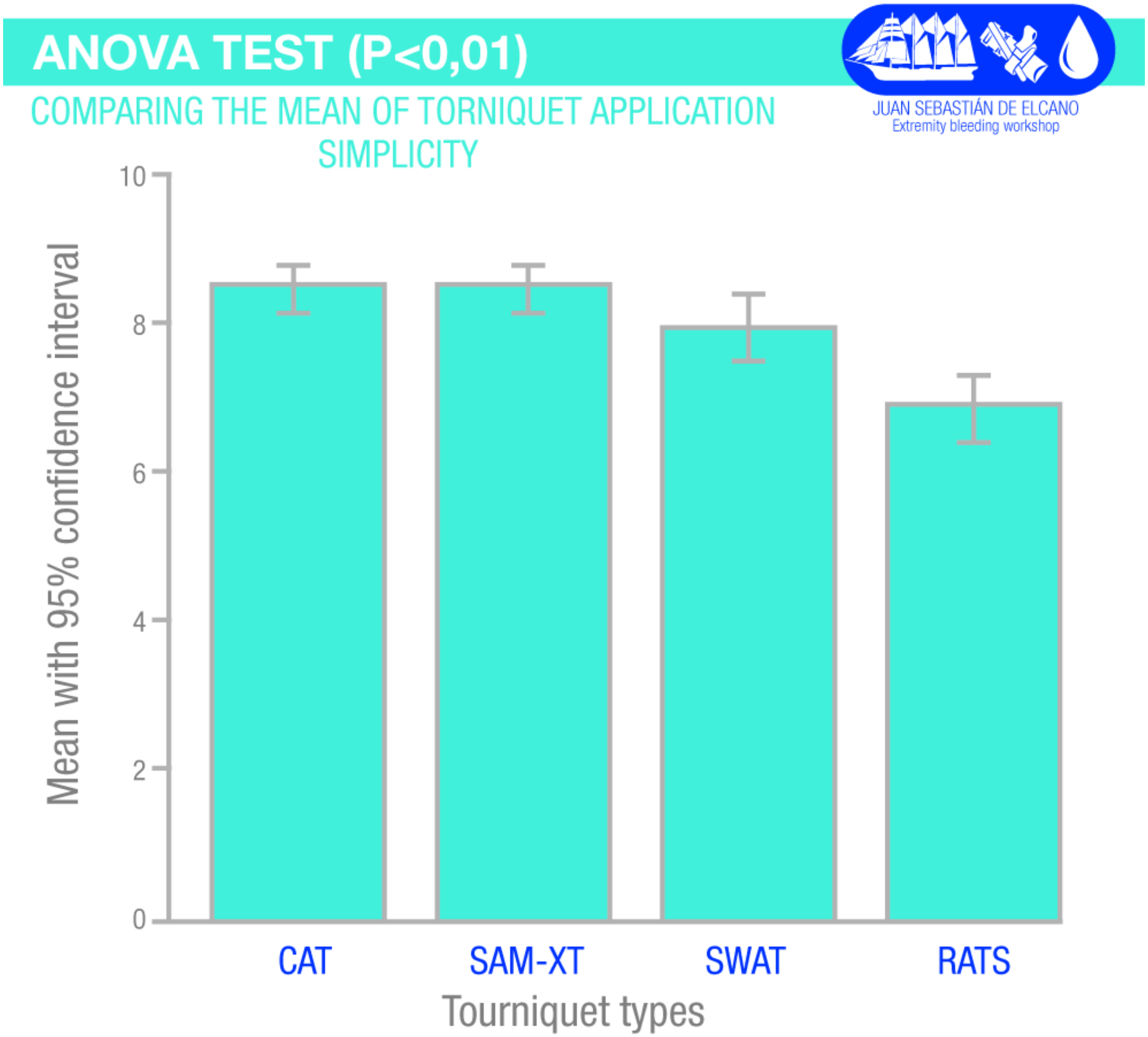
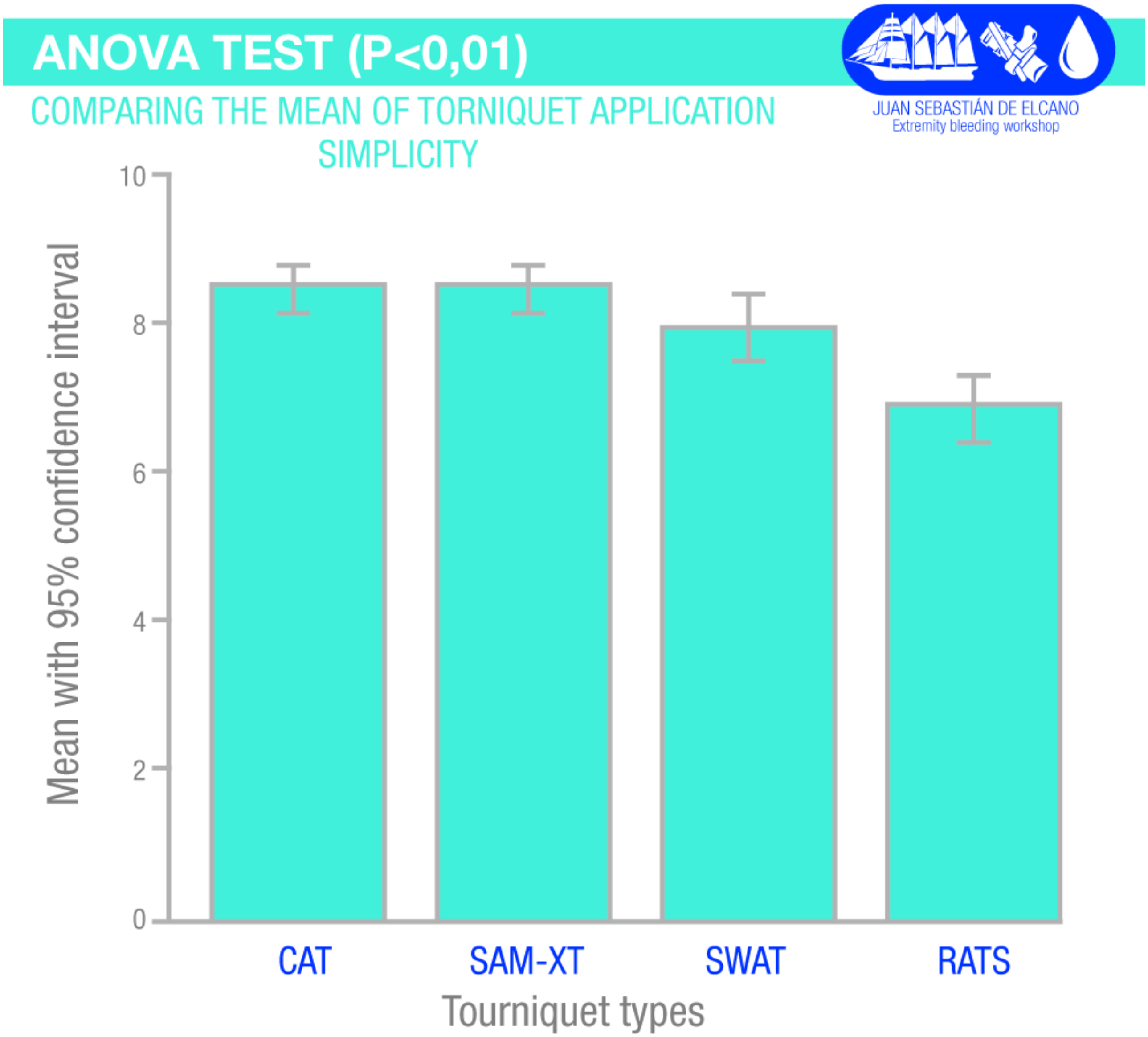


Figure 4

ANOVA test comparing the mean of tourniquet application simplicity. Although the tourniquets with a windlass mechanism (CAT-7 and SAM-XT) were considered simpler to use, statistical difference was only found for the RATS ($p<0.01$), which ranked the lowest among all four. (CAT- Combat application Tourniquet® Gen-7, SAM-XT Sam Application Tourniquet®, SWAT™ Stretch Wrap and Tuck Tourniquet, RATS® Rapid Application Tourniquet System).



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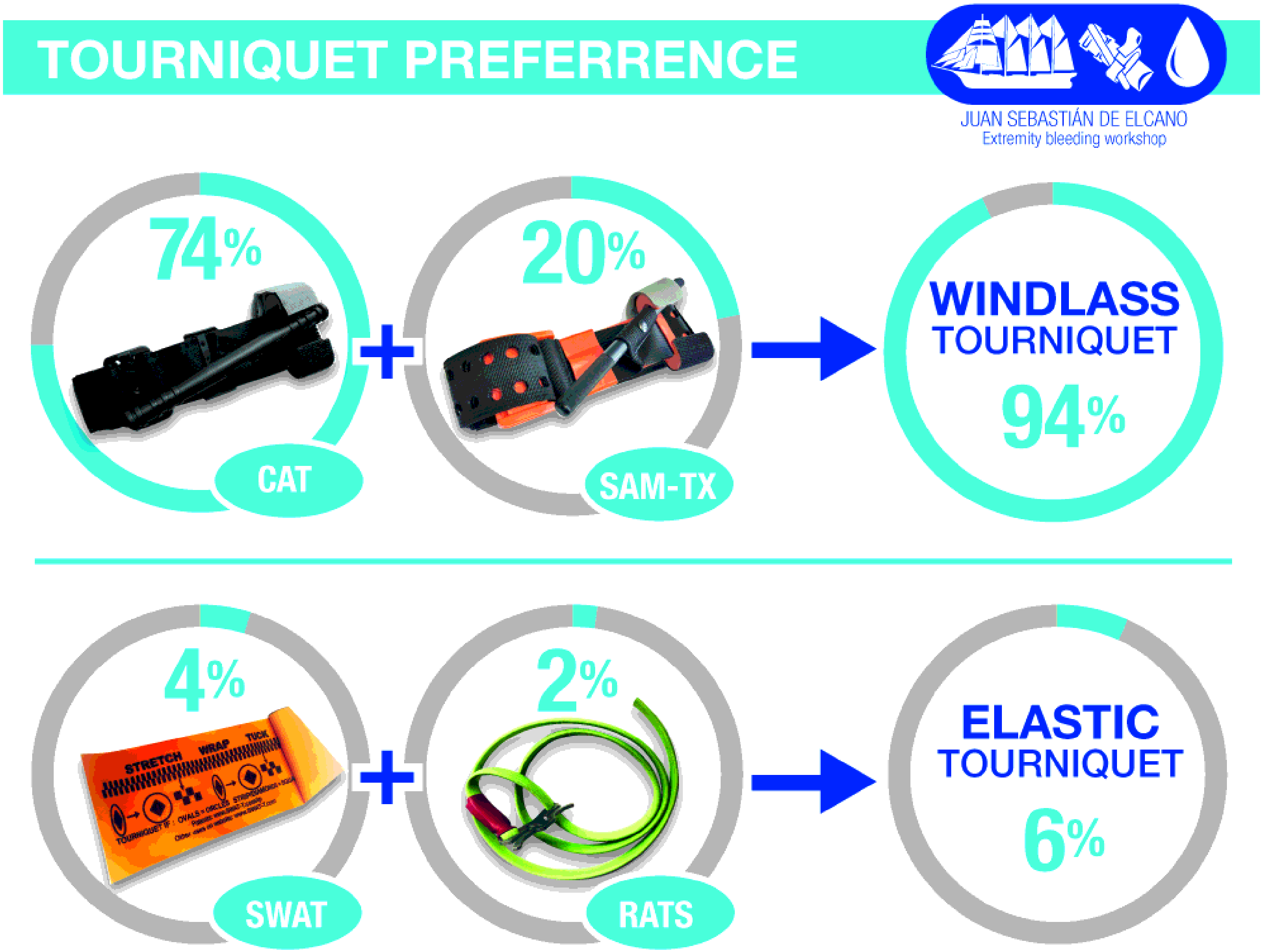
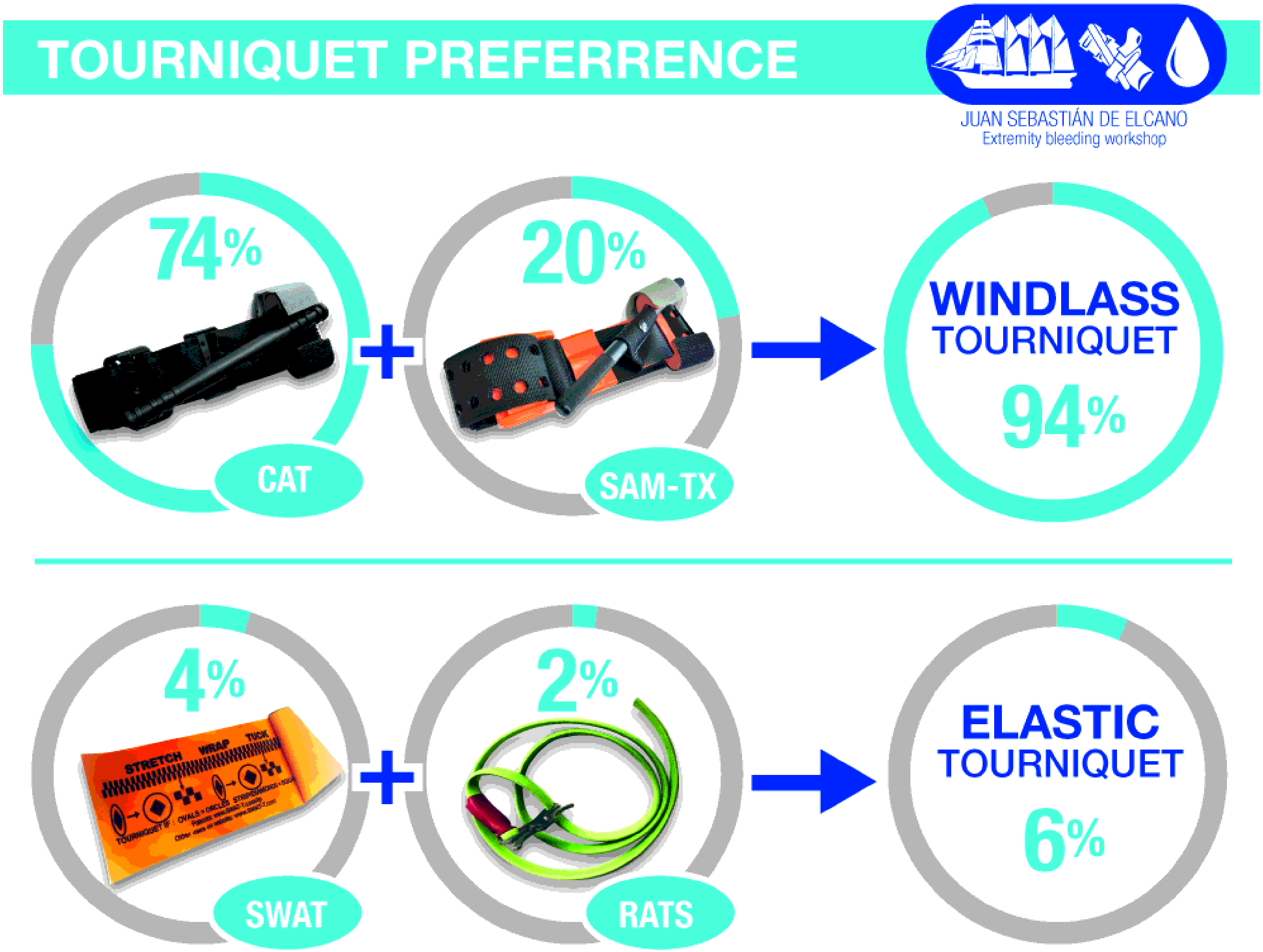


Figure 5

The percentages of tourniquet preference among the four devices tested are depicted individually and by the mechanism of vascular occlusion (windlass vs. elastic models). (CAT- Combat application Tourniquet® Gen-7, SAM-XT Sam Application Tourniquet®, SWAT™ Stretch Wrap and Tuck Tourniquet, RATS® Rapid Application Tourniquet System).



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