ANALYSIS OF THE DELIVERY OF MARITIME TELEHEALTH

BY

Colton David Hood

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CERTIFICATE OF APPROVAL

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This is to certify that the Master's capstone of

Colton David Hood

has been approved

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Vishnu Mohan M.D., M.B.I.

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Abstract

Telehealth is critical to the welfare of a large percentage of seafarers. The populations are remote and have a history of poor medical care largely due to inaccessibility. Throughout the years this barrier has been broken down first with the discovery of the radio with most of the remainder broken after the advent of real time satellite communication. Medical care to populations at sea continues to evolve but significant constraints still remain, such as limitations to the amount of bandwidth available to ships at sea. Outside this constraint we have largely moved past the proof of concept phase to provide high quality medical care at sea. Almost any technology can be adapted to be used at sea (either in real time or in a store-and-forward capacity), however, future decision-making and research and its applications deserve to be examined utilizing a specialized maritime framework. The framework should examine existing technologies and new technologies considering telemedicine best practices combined with the constraints brought by the current state of maritime health and technology infrastructure.

Introduction

The health of modern seafarers was transformed with the invention of the radio in the late 1890's. The first well documented utilization of the radio for medical advice was by Seamen's Church Institute of New York in 1920[1] and soon it spread to seafarers around the world. One of the longest standing Maritime Telemedicine Assistance Service (TMAS) systems providing Radio Medical Services (RMS) is the Foundation Centro Internazionale Radio Medico (CIRM) from Italy that has been in operation since 1935.[1] . This paper explores the literature including the state of technology used in telemedicine over time with a focus on the last three decades. Next it will study the technology utilized in the most recent literature including a survey of current maritime medical technology and finally suggestions on how to proceed with the advancement of maritime technology in the future.

Telemedicine at sea is critical to the shipping industry; in 2012 the total estimated cost of medical evacuations, for example being removed from the ship by helicopter while still at sea, was estimated to be up to 760 million euros worldwide.[2] Henny et al.[2] also estimated that the total cost of a single medical evacuation can be expected to cost 163,750 euros per evacuation. They also estimate that 1 in 5 ships experience a diversion, or unscheduled change in destination, due to a medical reason every year. The group estimated that they could reduce 20% of medical evacuations at a savings of 152 million euros in total with "judicious use" of TMAS services. The estimation of the reduction in medical evacuations was also supported by a study published by the Center for Naval Analysis in 2017 by Garcia et al.[3] who estimated a 17% reduction in evacuations at an estimated savings of 4,400 US dollars per vessel.

The Past

The 1990's

Prior to the use of satellite phones the radio and technologies such as the telex[2] (text transmission) were used at sea. Adoption and availability of satellite communication lead to the expansion of maritime telehealth in the 1990's. In 1998 Anogianakis et al.[4] reported on the European Union-financed MERMAID project which was a satellite and land based telemedicine system to support mariners at sea. When developing the system, they performed a survey of 1,853 vessels and at that time, they found that only 85% of vessels had personal computers and at least 55% had access to some form of satellite communication.

The system focused on utilizing the INMARSAT satellite system and ground stations to distribute the medical case load to multiple medical centers. MERMAID was thoroughly planned and implemented it included consideration for live video examinations, medical records, and locally stored medical guides for treatment at sea. Their planned software system was extensive including messaging, drug information, medical records, imaging support, audio/visual communication, with multiple languages supported among other features. Unfortunately, despite being a comprehensive solution, there is little mention of the MERMAID project after its initial stages in the late 1990's.

In the same decade, the United States Navy explored the cost effectiveness of telemedicine in a report written in 1997. Garcia et al.[3] analyzed the savings in preventing medical evacuations, reduced return-to-duty time and they found an increased quality of care and faster access to a higher-level of care. They found that, depending on the size of the ship, a complete telehealth loadout of equipment including technology such as the stethoscope, ophthalmoscope and dermascope could be indicated. A comprehensive loadout makes sense for a large aircraft carrier, but for a small ship, e-mail, internet, telephone and fax were the recommended technology. Due to the cost and constraints of bandwidth at the time, video communication was not recommended on small ships, but was found to be cost effective on aircraft carriers. They also reported an initiative to increase fleet wide ship bandwidth up to 1.5mbps by the year 2000, which is a significant speed, especially for the time. In comparison they report a bandwidth of less than 128kbps on INMARSAT satellite system at that time. This was an ambitious goal for the time considering 1.5mbps would support a modern video conferencing solution such as Zoom, which reports a bandwidth recommendation of 600kbps (up/down) for 1 on 1 video calling[5].

2000's

With the turn of the millennium telemedicine at sea started expanding rapidly. Throughout the decade we started to understand the burden of disease that was present at sea and started to utilize the new technologies developed throughout the decade. Ferguson et al. showed ship to shore emergency calls received in Aberdeen resulted in an 47% rate of evacuation per year averaged from 1996 to 2000; these were emergency calls referred from the UK Coastguard.[6] Mitchelson et al. updated the report from this TMAS in 2008 stating that 83% of calls from fishing vessels resulted in an evacuation with a rate of 75% for all others.[7] Interestingly they also report that due to TMAS assistance only one case was prevented from becoming an evacuation.[7] The most common medical emergencies reported were chest pain, abdominal pain, infection and neurological complaints.

A similar experience was reported by Westlund which included statistics for the Swedish TMAS from 1997, 2002, 2007 and 2009.[8] The report is of 1290 cases originating worldwide while reporting how technology was utilized in medical care over time. E-mail started at 2% use in 1997 and increased to 19% in 2009. Satellite mobile phone usage increased from 64% in 1997 to 88% in 2009 and the rate of digital photo use was 8% of all cases in the first six months of 2009. Lastly, the experience of the radio medical service at Singapore General Hospital from 1980 to 2002 shows they had shifted from radio, to telex and finally to satellite communication with a coverage area including portions of the Indian and Pacific oceans. The most common medical cases were abdominal pain, with or without vomiting and diarrhea, and musculoskeletal pain including minor trauma and burns. At the hospital in 2002 the most common mode of communication was the telephone.[9]

This decade also saw renewed interest in the utilization of advanced telemedicine equipment, especially with the promise of near real time communication. Despite these advances in 2009 Horneland[10] published concerns about the state of maritime telehealth, especially the state of use of advanced telemedicine equipment. One of the focuses was the use of ECG at sea, with a specific concern on aspects of being able to safely manage thrombolytics at sea; a limitation that can lower the practical value of detecting a ST-Elevation myocardial infarction (a heart attack) at sea. He also had concerns that for the EKG to be an effective tool, users must undergo further training in order to obtain them in a satisfactory manner.

Interestingly, some of these concerns were validated in a future study by Dehours et al. in 2012 showing difficulty with obtaining EKGs at sea with a failure up to 23% of the time.[11] Although Dehours did not study the quality of the information that was transmitted, Oldenburg, Baur and Schalich found in 2012 while using three different models of automatic external defibrillators that operators successfully transmitted EKG information to a remote provider 92% of the time.[12] In 2010 Alves et al. provided a review of 1,394 cardiovascular events on maritime vessels at sea. Regarding technology they mainly report on the use and efficacy of AED's but also suggest the use of multi-parameter monitors and the transmission of EKG data in support of telemedicine.[13] Despite Horneland's concern about the utilization of ECG, the review also implies support for use of video at sea and suggests deeper collaboration and cooperation between TMAS systems and increasing the minimum amount of medical training for seafarers.[10]

Regarding further advances in technology at sea, Nikolic et al. made a case to bring ultrasound to vessels in 2009.[14] This was achieved in the context of providing additional ultrasound training within the existing 52 hour medical training provided by the Faculty of Maritime Studies in Rijeka, Croatia. After 90 minutes of additional training, operators were able to correctly present pathology in 57% of kidney cases and 80% of gallbladder cases; however, they missed pathology 29% of the time in kidney stones and 13% of the time in gall bladder pathology. They had a rate of nondiagnostic scans 14% and 7% of the time respectively. At the time the cost of their equipment was about 9,000 dollars USD compared to a reported rate of 5,000 to 10,000 dollars per day for the estimated cost of a ship diversion. Interestingly they also reported a problem with continuity of care as the ship moved from port to port as the TMAS systems did not always overlap. They did not directly address the technical requirements for teleultrasound; however, they did report that X-ray and other diagnostic pictures were able to be transmitted successfully with INMARSAT-A phones from Somalia to Walter Reed Hospital.[15]

Research during the decade also studied the efficacy of portable biomedical devices, such as the electrocardiograph. Gortzis et al. studied the data precision, peripheral modules reliability and data transmission quality of ECG machine on a cruise liner.[16] The measures studied were highly technical: the first measure is data precision, which in this study is the level of agreement of data measured between two devices. Second was peripheral modules reliability, which was measured by how easy the system was to use and how long it took to place electrodes. Third was data transmission quality, which was not a factor given stable satellite communication during the study period. They essentially found that devices that had better data precision were typically more difficult to use. They encouraged careful investigation of integrating biomedical devices into telemedicine services.

Building on this was one of the most thorough reviews of the practical analysis of maritime telehealth from the Department of the Navy by Reed, Burr and Mecler.[17] They created a framework based upon telemedicine evaluation framework of Yawn[18] and framework and human factor considerations of Yellowlees.[19] Reed et al.[17] assessed a telemedicine system through categories by looking at the technologies task domain, tools and equipment, evaluation of setting, integration, cost, satisfaction and human factors evaluation.

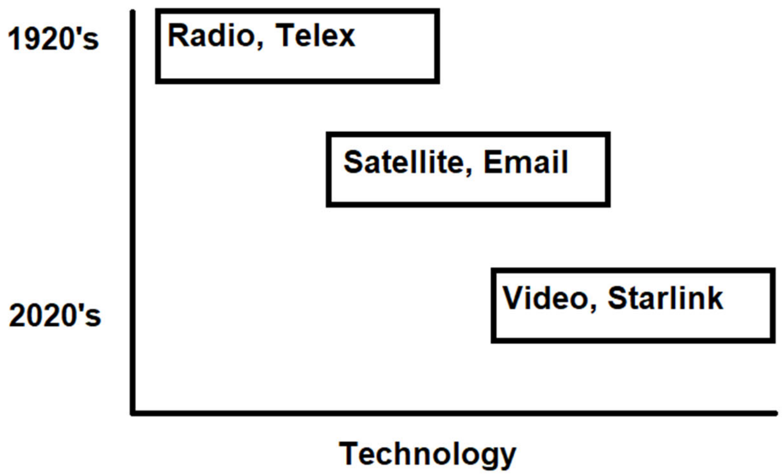

Figure 1. Evolution of maritime telehealth technology over time with considerations for the future.

The 2010's

The next decade brought a rapid evolution of technology with an increase in the ability to utilize more bandwidth consuming technology such as transmission of high-quality pictures. Dehours et al. in 2017 suggested a few ways in which transmission of pictures could make a difference to their TMAS the Toulouse Tele-Medical Assistance Service in France.[20] They reported 5 cases: two of which involved transmissions of electrocardiographic information, two managed dermatology complaints and one dental complaint. Given these are all very common afflictions for the seafaring population, they suggested continued development of this technology to better support maritime health.[21] They also reported a case series of traumatic injuries, with procedures, including foreign body removal from a cornea, laceration repair and nail trephination. These procedures and their outcomes were assessed by the transmission of still photographs. They report about 1/3 of their consultations in 2016 involved photos. Dehours et al. concluded that given the success of sending still photographs further consideration should be given to real time video for management of similar cases at sea. Management of maritime complaints using photographs was echoed in a review by Dahl in 2014 on teledermatology with a focus on training of how to take better photos at sea, and using photos as a store and forward technology to support dermatology complaints at sea.[22]

Mahdi and Amenta reported in 2016 that the Centro Internazional Radio Medico felt with the adoption of satellite communication in their population in the 1990's had led to the ability to move to real time telemedicine consultation. They reported having advanced technology available including the ability to gather vitals and capture image;, they advocated to provide a packaged system to gather this information.[23]

Woldaregay et al. showed in a 2015 systematic review that missions to the arctic were supported by a diverse set of technologies and settings including at sea and offshore and in accident and emergency situations. Arctic missions were most commonly supported by satellite 28% and mobile phone 27% with video modalities being used 27% of the time, pictures 25% of the time with audio 19% of the time and text 17% of the time. These numbers were derived from the published literature.[24]

The literature of the decade also consists of the experience of many TMAS systems and the technology that they have utilized over time. Westlund, Attaval, Nilsson et al. reported from 1997 to 2012 the technology utilized has shifted from the use of VHF, radio and fax to the use of e-mail and satellite phone with digital photo utilization starting in 2002. The most common complaints for seafarers that they managed were eye 50%, musculoskeletal 40%, neurological 38% and skin complaints 38%.[25]

Mulic and Sumic from the University of Split in Croatia reported their experiences utilizing both radio and satellite, email and fax to provide medical care at sea.[26] From 2014 to 2017 the Turkish TMAS reviewed 5,080 cases, their most common complaint among seafarers were related to illness of the digestive system and skin disorders and overall they had a 10% evacuation rate. They received communications through email or telephone, however, in rare cases they still used fax as a modality of communication. [27]

There was a unique experience from the Oslo-Kiel-Oslo ferry which carried 2,600 passengers daily on which a paramedic is utilized on board to provide medical support. On the ferry the paramedic was supported by a telemedicine physician when considering evacuations, otherwise, telemedical support is limited. This system was well received although the ferry ride is fairly short at just shy of 4 hours.[28]

This decade also brings forward some very interesting issues including legal issues in Maritime Telehealth, research, and other technological improvements. MacLachlan, Kavanagh and Kay reported in 2012 in a systematic review of 198 papers a few themes of research healthcare access, delivery and integration, telehealth, and communicable and non-communicable disease and psychological functional and health.[29] Telehealth only had 15 publications, 7.58% of the total. Their article focuses on the need for more research considering the diverse populations in both ethno-geographic makeup and purpose at sea. They also noted there are very few randomized trials for healthcare at sea.

Ricci and his colleges outlined some of the medico-legal considerations of providing medical support to ships at sea.[30] In general, the Captain is responsible for the health and wellness of passengers and crew at sea with duties including timely and appropriate medical care for ill or injured on the vessel. When considering who is liable for injury at sea this responsibility can be shared by both the Captain and in the case of telehealth the remote physician, depending on whose decisions lead to the failure to occur. Specifically, in the United States the physician responsibility for medical malpractice at sea is a culpable one. Pharmacy regulations were addressed by Nittari et al.[31] who proposed a computerized database in order to ensure compliance with multinational rules for medications that should be available in a ships pharmacy. Their first attempt was to ensure compliance with Italian regulations. This is a support technology that can decrease medication mistakes and ensure medications are not expired and available to mariners at sea.

One of the most important publications in our report was a careful study on the patterns of illness and injury, specifically on US flagged ships. Lefkowitz et al.[32] showed that through the analysis of 1339 cases among American sailors, illness involved 68% of cases with injury involving 32%. The most common injuries were to the upper extremity at 34%, lower extremity at 22% and back at 21%. The most common illness was categorized as dental 26% of the time, respiratory 19% of the time, dermatological 14% and gastrointestinal 10%. To contrast this, injuries to the arm or shoulder, ankle, back, chest and abdomen were most commonly associated with being unfit for duty. Regarding illness; endocrine, psychiatric, cardiovascular and gastrointestinal complaints lead to being unfit for duty.

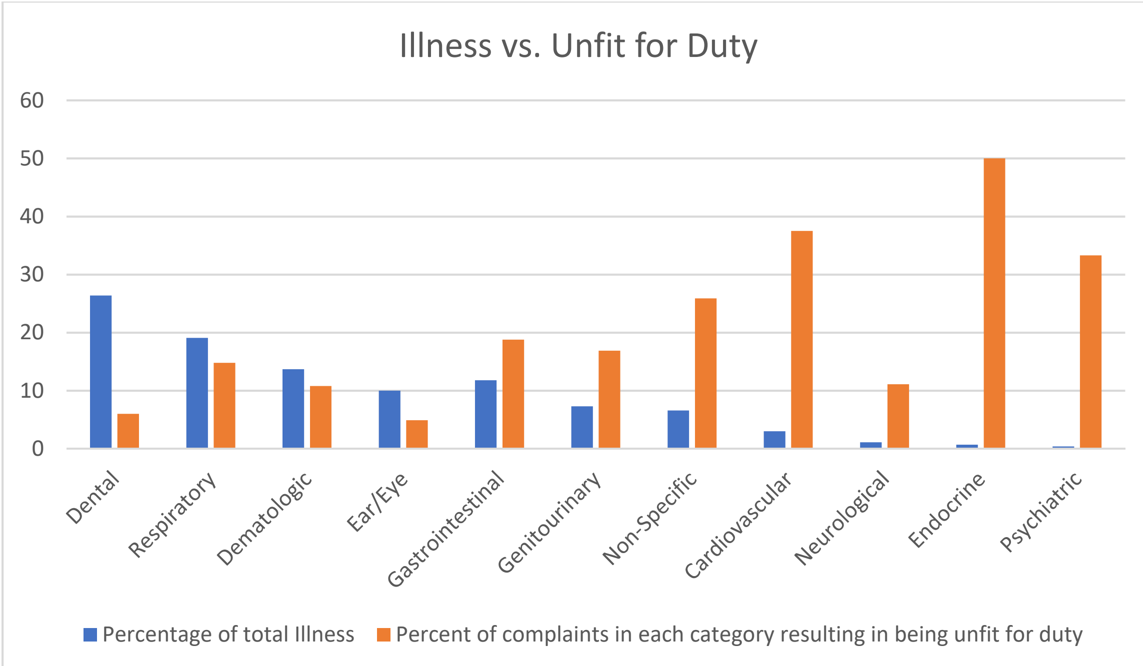

Figure 2. Adapted from Lefkowitz et al.[24, 32] most common illness by percentage compared to what percentage of illness cause a mariner to be unfit for duty.

It is important to report that the incidence of these complaints varies wildly from only 3 cases of psychiatric illness to 147 injuries of the upper extremity.[32] Grappasonni, Petrelli and Amenta showed in 2011 the cause of death of all the patients at the Centro Internazionale Radio Medico over the last 25 years.[33] They had 383 deaths out of 29,146 patient files over the last 25 years with the most common causes being classified as disease of the circulatory system including ischemic heart disease and traumatic including head injuries and falls. Reports such as these are very meaningful in understanding how we can best apply technology, among other solutions, to help safeguard against these rare but tragic events at sea.

The Present

A very recent 2019 study by Schalhorn, Richmond and Schalhorn discuss a case of syphilitic uveitis in a U.S. Navy sailor that was diagnosed through remote consultation with an ophthalmologist in 2019. They were able make the diagnosis through real time teleconsultation and through transmission of slit lamp and skin pictures to the remote providers.[34] Another recent development was presented by Henes et al. where they successfully launched teleradiology service for cruise ships at sea. They transmitted 75 radiographs as part of 47 radiological studies. Interestingly they reported that the quality of all the images was adequate and there were no obvious limitations to transmission of plain radiographs.[35] Understanding how maritime telehealth has developed over time is of key importance to understanding how technology can be applied in the future.

To better understand the limitations experienced by seafarers today, we created a mixed methods survey of Medical Officers and vessel owners or operators that was administered after obtaining institutional IRB approval. Not only did we seek to understand the current state of telehealth technology at sea but we also exclusively looked at US flagged ships, which is a population of mariners that is seldom studied with the majority of the literature reported so far originating from across the globe. The survey was distributed to administrative contacts in 24 maritime organizations who then forwarded it to their medical officers and other representatives.

We received a total of 12 responses to the medical officer survey from 3 vessels. As far as we are aware all organizations surveyed only operate US flagged vessels and they consist of the shipping, cruise, fishing, research, seafarer training and deep-water support services. Our survey tools can be found in the appendix of this report.

Results from the vessel survey are as follows: two vessels reported having the Fleet Broad Band service for connectivity, one vessel had HiSeasNet (a satellite service for oceanographic ships) and one reported having VSAT (Very Small Aperture Terminal) or satellite connectivity. One ship reported their available bandwidth as “528kb/264kb”. All ships reported having computers available and two ships reported having commercial packaged telemedicine systems such as Tempus telemedicine unit and one ship reported having a Digigone telemedicine kit.

The medical officers had an average experience of 8.5 years with a maximum of 18 years and a minimum of one year. Formal medical training among providers can be seen in Table 1.

Medical Training (number of medical officers)	
Standards of Training, Certification, and Watchkeeping	8
CPR	6
First Aid	6
MPIC	6
Basic Life Support	5
Advanced Cardiac Life Support	1
PHTLS (Prehospital Trauma Life Support)	1
Registered Nurse	4
First Responder	1
Medical Doctor	4

Table 1. Medical training of surveyed medical officers

Their case distribution was 2 to 15 cases a year with an average of 5.7 cases; they averaged 2.8 telehealth consults per year with a range from 0 to 10. The distribution of technology among cases is show in Table 2.

Total Number of Medical Cases	69
Total Telemedicine Cases	29
Total Cases using E-mail	27
Total Cases using Photos	13
Total Cases using Video	5

Table 2. Summary stats of cases by technology

Despite gathering this information in 2020 we still see a very small uptake in the use of video used for telehealth consultation but nearly ubiquitous use of e-mail. As shown in Figure 1. the medical officers' communication preference is to use the phone which was reported 8 times, email reported 3 times, and lastly video reported just one time.

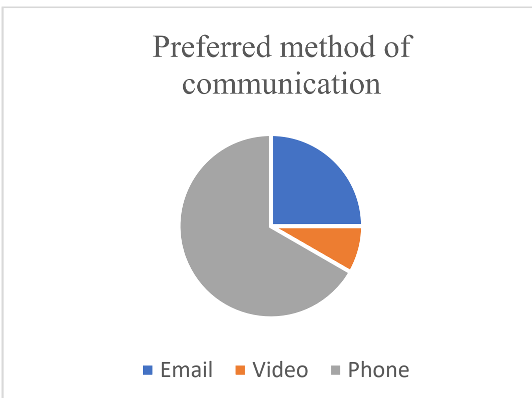

Figure 3. Preferred method of communication

Results

Regarding telehealth overall, real time audio communication primarily utilizing satellite phone seems to be an adequate technology, for example one respondent noted:

"Mainly limited to phone, which works great.",

There are however occasional problems even with this “safe” modality. Another respondent noted:

“Phone communications are sometime glitchy”.

Regarding e-mail as a modality it is largely well accepted, and we saw it used in the majority of cases. There is a sentiment that it feels delayed:

“*The delay time getting information can be long and I will have to go to sleep”.*

It may also be occasionally limited by bandwidth considerations:

“Occasionally we have had poor internet connections, and that will make it difficult to send pictures or other documents back and forth via email”.

Lastly, we approach video which is the least used and appears to have the most limitations. There is a sentiment that bandwidth and connection limit the use of video, except in one case:

“*We used real time video via "Whatsap*" *because we found that it was a more clear connection than our satellite phones*.”

There seems to be a clear theme for the desire to have access to real time video communication at sea:

“*doing a face to face discussion where I could fully present the case with clarity*.”

There is also a desire to have improved bandwidth at sea with the example of:

“*Fast Internet connections will improve our options*.”

A summary of the sentiments by topic is available in Table 3.

Telemedicine	“We used real time video via "Whatsap" because we found that it was a more clear connection than our satellite phones.” “Phone communications are sometime glitchy” “None, rapid response on satellite communications” “Mainly limited to phone, which works great.” “we are usually able to do everything we need to do over the satellite phone.” “Sometimes I get frustrated with phone connection” “We have experienced problems with the previous satellite communications provider.”
Email	“The delay time getting information can be long and I will have to go to sleep” “None (except for when the internet connection is slow)” “Occasionally we have had poor internet connections, and that will make it difficult to send pictures or other documents back and forth via email” “With email sometimes there are questions that are asked by * that I already asked and now have to type and send another email adding to another delay”

Video	"some times the delay is long and we talk over each other" "Slow internet bandwidth while at sea. It is faster and more efficient to just use the phone & email." "Working on getting more bandwidth aboard vessel to more effectively utilize video"
Technology Improvement	"E-mail with attached pictures (if required) probably is good way but video telemedicine is probably better" "Fast Internet connections will improve our options." "Pictures, video" "I would go for telehealth video" "Clear and strong internet connection signal pertaining for Video telecommunication" "doing a face to face discussion where I could fully present the case with clarity." "A combination of phone, email, and video is the best way to facilitate telehealth at sea. Each method of communication can be very useful in a variety of situations."

Table 3. Themes by topic, with representative quotes from subjects

Limitations

We have some important limitations in our survey. First, it was limited to only US flagged ships. The precise proportion of response is difficult to determine because we distributed the research study to the overseeing organizations and not directly to the medical officers themselves. Our overall response rate (n=15) was limited by the current restrictions imposed by the COVID-19 pandemic, which has caused a slowdown in the maritime industry especially during the distribution of the survey and will take some time to return to normal.

The Future

Through our literature review and survey we tried to understand the past and current state of technology and utilization with respect to the delivery of maritime healthcare and understand its current limitations. Analysis of the survey coupled with a robust review of the literature helped to inform how we can improve healthcare to mariners with a focus on telehealth and technology. To this end using a framework developed by Yawn[18] and adapted by Reed et al.[17] provides a good system for evaluation of telehealth at sea, specifically using the categories of task domain, tools and equipment, evaluation of setting, integration, cost, satisfaction and human factors evaluation. While there are likely other frameworks, we suggest following one and using it not only to critically evaluate current programs but it is also helpful to generate hypothesis for future research and applications of telehealth.

Task domains, as defined in this framework, are the aspect of sensory perception that is projected via telehealth. The visual domain is well represented especially regarding dermatology complaints.[21, 22, 24] Mobile phones are all but ubiquitous at this time and it may be worth investigating their use compared to high quality digital cameras, especially ones that can focus on rashes up close to assist with frequent dermatology complaints at sea. There is room for improvement in the real time video domain with bandwidth remaining a constraint in 2020, with one ship reporting “528kb/264kb”, download and upload speed in our survey. The auditory domain is well established at sea given radio technology is ubiquitous; satellite phone is nearly ubiquitous, and one could argue even with the meager bandwidth uncovered in our survey, voice over the internet is almost always feasible. Technologies that could transmit heart or breath sounds could be of some benefit such as an electronic stethoscope, while real-time transmission may not be practical, a store and forward system should be possible. Most importantly applicability of augmenting some of these task domains is predicated by the amount of training by medical officers, which can vary the amount of physical exam findings that can be reported with accuracy.

Understanding the setting where equipment is utilized is critical for the application of new maritime telehealth technologies. The work performed on the ship demands consideration: this varies from cruise lines to dry (and wet) cargo ships, all have their unique needs. Simple considerations, such as if the equipment or system can be brought to the patient or if the patient needs to be able to present themselves. This simple pitfall was observed in our survey, where the only phone was located on the bridge. Considerations of this domain are also how well trained the Medical Officer is in using the system or equipment, which overlaps with human factors as well.

The third domain to consider in the future is integration and Yawn mainly put this in the context of workflow. The technology or intervention needs to be adaptable to duties on a vessel and outcomes need to be evaluated both in respect to their clinical and operational aspects. From the literature presented this domain is best illustrated by providing teleradiology to cruise ships at sea.[35] Consideration to things such as the difference in time zone impacts routine on a ship and remote medical providers shows that this domain continues to warrant consideration.

The domain regarding cost cannot be ignored; technology has become far more accessible since the early 90's but understanding the return on investment is always imperative to running a business. One could consider the cost-benefit report by Garcia et al.[3] as a guide in and of itself. Scale is also an important consideration, the more people the device serves should improve its cost effectiveness.

Satisfaction has been a well-studied parameter and Yawn makes a point of including it in her framework with considerations of the patient, clinician and the community. I think studies that consider satisfaction[11, 16] help to make sense, from a commercial standpoint, what technologies are possible. This is just one simple factor in the domain of satisfaction when considering further products or research.

Additional information about human factors in this framework comes from Yellowlees. In 1997[19] he focused on seven principles for the successful development of a telemedicine system including pragmatic development, ownership by clinicians and users, bottom up support, user-friendliness, well trained and supported. Systems should also be evaluated in clinical and user-friendly manner and lastly shared with others, which is at the core purpose of this paper and research. It is worth mentioning he followed this research in his own comprehensive six question Who, What, When, Where, Why and How framework in 1998 which focuses on what he states is a practical evaluation of telehealth systems.[36]

Task Domain	**More exploration of what task domains are worth replacing, consider heart and breath sounds.**
Setting	**Understand injury and illness may vary by population and ship type, focus may be on specific settings. Balancing medical training and augmenting a task domain with technology.**
Integration	**Focus on how maritime telehealth impacts workflows on each type of vessel.**
Satisfaction	**Focus on mariners, operators and TMAS physicians.**
Human Factors	**Ownership by both seafarers and owners and TMAS systems.**

Table 4. Framework recommendations with a focus on maritime telehealth

Conclusion

In some ways maritime telehealth is a constantly shifting landscape depending on where in the world you are from, where you are located at the time of emergency and who you have arranged to take care of your health needs at sea. There is a worldwide network of systems that provide emergency care but, as previously stated, there is room for improvement on sharing effective methods and collaborating to provide the best care possible for mariners at sea. There has been by no means lack of trying, application of all manners of advanced telehealth technology and systems can be traced back as far back as the considerations of the Navy in 1997.[3] Constraints however can be significant including small crews and low bandwidth. Rigorously planned, tested and researched technologies that may have very niche applications may be the way to advance telehealth technology for mariners at sea.

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Appendix 1. Medical Officer Survey.

Questions to Medical Officers:

The timeframe for the questions is specified as the last year or last month in your duties as a medical officer (please do not count time off or time spent in another job).

Please refrain from using names of any specific individuals in your responses.

How long have you been a medical officer (Please specify in years, round to the nearest year)?

Do you have any formal medical training? (Select as many as apply, you may also write in for other)

☐ RN,MD ☐ EMT/Paramedic ☐ CPR ☐ Basic life support ☐ Advanced cardiac life support ☐ First Aid ☐ First Responder ☐ STCW (Standards of Training, Certification, and Watchkeeping) ☐ MPIC (Medical Person In Charge) ☐ Other ____________

How many maritime medical cases have you been involved **in in the last year** as a medical officer?

How many maritime medical cases have you been involved **in the last month** as a medical officer?

How many times have you used telemedicine (remote medical support using phone, email or video) in a maritime medical case **In the last year**?

How many times have you used telemedicine (remote medical support using phone, email or video) in a maritime medical case **in the last month**?

Were there any technological limitations to your telemedicine encounters **in the last year**?

Please explain:

Were there any technological limitations to your telemedicine encounters **in the last month**?

Please explain:

How many times have you used real time video during a maritime medical encounter **in the last year**?

How many times have you used real time video during a maritime medical encounter **in the last month**? _

Were there any technological limitations using real time video during **the last year?**

Please explain:

Were there any technological limitations using real time video during **the last month?**

Please explain:

How many times have you used e-mail to communicate with a remote provider during a maritime medical encounter **in the last year?**

How many times have you used e-mail to communicate with a remote provider during a maritime medical encounter **in the last month?**

Were there any technological limitations for using email to communicate with a remote provider **in the last year**? Please explain:

Were there any technological limitations for using email to communicate with a remote provider **in the last month**? Please explain:

How many times have you sent pictures to a remote provider as a part of a maritime case **in the last year?**

How many times have you sent pictures to a remote provider as a part of a maritime case **in the last month?**

Were there any technological limitations for sharing images **during the last year**?

Were there any technological limitations for sharing images **during the last month**?

Have you used any other remote diagnostic technologies (devices that interact directly with a remote provider) during a remote medical case **in the last year**? (Select as many as apply, you may also write in for other)

☐ Stethoscope ☐ Otoscope ☐ Ophthalmoscope ☐ ECG/EKG ☐ X-Ray ☐ Ultrasound

☐ Blood pressure cuff (Spyngomamoeter) ☐ Dermatoscope ☐ General inspection camera ☐ Glucometer ☐ Thermometer ☐ Oxygen saturation (Pulse oximetry) ☐ Cardiac monitor (telemetry) ☐ Other ______________

Have you used any other remote diagnostic technologies (devices that interact directly with a remote provider) during a remote medical case **in the last month**? (Select as many as apply, you may also write in for other)

☐ Stethoscope ☐ Otoscope ☐ Ophthalmoscope ☐ ECG/EKG ☐ X-Ray ☐ Ultrasound ☐ Blood pressure cuff (Spyngomamoeter) ☐ Dermatoscope ☐ General inspection camera ☐ Glucometer ☐ Thermometer ☐ Oxygen saturation (Pulse oximetry) ☐ Cardiac monitor (telemetry) ☐ Other ______________

What is your preferred method of communication with a remote medical provider? (select only one)

☐ Phone ☐ E-Mail ☐ Video

Do you feel that you are limited by your available equipment and technology in obtaining a consultation with a remote medical provider?

Please explain:

Are there any technological barriers to communication with a remote medical provider?

Please explain:

Have equipment or technology malfunctions lead to complications during a remote medical consultation in the last year?

Please explain:

What equipment or technology do you feel best facilitate telehealth in maritime medical care?

Please explain:

Appendix 2. Technical Questions for Employers

Technical questions for employer/owner:

What types of internet connectivity do your ships have?

Do you provide access to computers that have internet access?

Are any mobile devices provided to crew for official purposes?

Do you know what bandwidth and latency are available to your ships at sea?

Do you provide access to any advanced telehealth equipment at sea? (Select as many as apply, you may also write in for other)

☐ Stethoscope ☐ Otoscope ☐ Ophthalmoscope ☐ ECG/EKG ☐ X-Ray ☐ Ultrasound ☐ Blood pressure cuff (Spyngomamoeter) ☐ Dermatoscope ☐ General inspection camera ☐ Glucometer ☐ Thermometer ☐ Oxygen saturation (Pulse oximetry) ☐ Cardiac monitor (telemetry) ☐ Other ______________