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Operation Airway: The First Sustainable, Multidisciplinary, Pediatric Airway Surgical Mission

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Abstract

Objective: This study aimed to describe the development and implementation of the first sustainable, multidisciplinary, pediatric airway surgical mission in an underserved country.

Methods: This prospective, qualitative study was conducted for the first 4 Operation Airway missions in Quito, Ecuador. The major goals of the missions were to assist children with aerodigestive abnormalities, create a sustainable program where the local team could independently provide for their own patient population, develop an educational curriculum and training program for the local team, and cultivate a collaborative approach to provide successful multidisciplinary care.

Results: Twenty patients ages 4 months to 21 years were included. Twenty-three bronchoscopies, 5 salivary procedures, 2 tracheostomies, 1 T-tube placement, 1 tracheocutaneous fistula closure, 2 open granuloma excisions, and 6 laryngotracheal reconstructions (LTRs) were performed. All LTR patients were decannulated. A new type of LTR (1.5 stage) was developed to meet special mission circumstances. Two videofluoroscopic swallow studies and 40 bedside swallow evaluations were performed. One local pediatric otolaryngologist, 1 pediatric surgeon, 3 anesthesiologists, 7 intensivists, 16 nurses, and 2 speech-language pathologists have received training. More than 25 hours of lectures were given, and a website was created collaboratively for educational and informational dissemination (http://www.masseyeandear.org/specialties/pediatrics/pediatric-ent/airway/OperationAirway/).

Conclusion: We demonstrated the successful creation of the first mission stemming from a teaching institution with the goal of developing a sustainable, autonomous surgical airway program.

Keywords

Operation Airway, pediatric, surgical, mission

Introduction

Common international missions with otolaryngology support typically involve cleft lip and palate deformities, microtia, and chronic ear disease. Although the goals of these missions are laudable and great international medical support is provided, the aforementioned missions tend to seek out children who are otherwise healthy to perform surgeries that sometimes could be viewed as elective. There is currently a lack of support for airway reconstruction in these same international settings. Many medically complex children suffer catastrophic complications and death from tracheostomy tube dependence. The estimated tracheostomy-related mortality rate in the United States ranges from 0.5% to 2%.[1,2] If the mortality rate is this high in the United States, one can only infer that this rate is much higher in underserved countries. These countries lack resources to

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adequately care for children with tracheostomies and lack the knowledge to perform airway reconstructions. In response to this dire need, we founded Operation Airway.

Any international surgical outreach initiative should follow a logical, well-organized set of principles. Through our prior work with Global Smile Foundation (GSF), we modeled our mission based on the preoperative, perioperative, and postoperative stages outlined by GSF.[3,4] The preoperative stage consists of the site selection, site visit, and trip preparation. The perioperative stage involves preoperative patient screening, case selection, and operative care. The postoperative stage focuses on surveillance and follow-up.

The GSF model was originally designed for cleft lip and palate missions, and we needed to tailor our mission paradigm to complex pediatric airway patients. Thus, the goals of Operation Airway were to assist those children with aerodigestive abnormalities, create a sustainable program where the local team could independently provide for their own patient population, develop an educational curriculum and training program for the local team, and cultivate a collaborative approach to provide successful multidisciplinary care. The children's needs were often a matter of life or death. Capacity building through training and education allowed the program to be sustained by the local team, as they were provided the necessary tools. Optimal treatment of these patients demanded multidisciplinary aerodigestive care.

The objective of this study was to describe the development and implementation of the first sustainable, multidisciplinary, pediatric airway surgical mission in an underserved country.

Methods

The Institutional Review Board at Massachusetts Eye and Ear Infirmary approved this study. We conducted a prospective, qualitative study of the first 4 Operation Airway missions from 2010 to 2013 in Quito, Ecuador. Patients ages 21 years and younger were included. The patients were originally screened as potential candidates by the local pediatric otolaryngologist or surgeon.

Helping Those Children in Need

To help complex pediatric airway patients in Ecuador, a logical, well-organized set of principles was developed. The stages outlined by GSF for their cleft missions[3,4] were adapted for the specific needs of Operation Airway. In the preoperative stage, the first task was to obtain a written invitation from a local Ecuadorian government official. Once a formal invitation was issued, we ensured that a true need existed for pediatric airway surgery services, located a hospital capable of providing these services, established a local medical team with a pediatric otolaryngologist or surgeon willing to perform preoperative and postoperative care, and made contact with a local coordinator to assist with trip planning and logistics. To determine that a true need for pediatric airway surgical services existed, we maintained close contact with a local pediatric pulmonologist, who followed several tracheostomy-dependent patients, and a public relations campaign occurred on the radio and in the newspaper in the host country. The local pediatrician or pediatric pulmonologist ensured proper treatment of reflux preoperatively. Tracheostomy care for these patients involved no official standards of care. Tracheostomy tubes are often boiled and placed back into patients (sometimes resulting in structural failure of the tubes while inside patients), and inadequate suction supplies and training lead to plugging and accidental decannulation incidents. Patients with tracheostomies live in special care facilities, where the tracheostomy-related morbidity and mortality rates are presumed to be quite high (although this is difficult to quantify).

In terms of financial planning, the cost of each mission to Ecuador was approximately $70 000. The average cost for 1 patient to undergo airway reconstruction with a 10-day postoperative pediatric intensive care unit (PICU) stay at our institution in the United States is approximately $35 000. The majority of the funding came from philanthropic donations and charity runs (Boston Marathon), but the Massachusetts Eye and Ear Infirmary also provided supplemental funds. The local hospital in Quito covered expenses for labs, radiology, and other ancillary services. The local team paid for meals and arranged lodging at a discounted rate.

The next step in the preoperative stage was to conduct 2 separate site visits. The first visit was to a tertiary care hospital in Quito and was completed by the senior surgeon (C.J.H.) and intensivist (N.N.). The local hospital was inspected to ensure that pediatric airway surgery could occur safely in the operating room and that adequate postoperative intensive care was available. This was the first opportunity to network with the local medical staff, determine the credentialing requirements, and identify any potential obstacles to providing critical pediatric airway care. The initial evaluations and bronchoscopies occurred at this time to determine which patients might require airway surgery during the upcoming missions. The second site visit was by the local Ecuadorian team to the Massachusetts Eye and Ear Infirmary. This 2-way model maximized capacity building. The specific tasks accomplished during this visit will be elaborated on in the education and training section to follow.

Trip preparation was the next step in the preoperative stage. We developed a comprehensive staffing algorithm for our pediatric airway mission consisting of 1 staff pediatric airway surgeon, 1 fellow pediatric airway surgeon, 1 pediatric anesthesiologist, 2 pediatric intensivists, 2 pediatric

Table 1. Contents of Laryngotracheal Reconstruction Set.

Instrument	Number
Scleral hook	4
Double wide skin hook	2
Right angled clamp	2
Cottle elevator	1
Freer elevator	1
Duck bill elevator	1
Scalpel	2
Beaver blade	2
Rosen knife	2
Iris scissors	1
Mayo scissors	1
Jeweler's bipolar forceps	1
Forceps	1
0.5 mm forceps	2
Cutting block	1
Caliper	1
Gelpi retractor	2
Senn retractor	4
Ragnell retractor	2
Blair retractor	2
Trach spreader	1
Trach hook	1
Needle holders	2
Size 5 suction	2

operative nurses, and 1 speech-language pathologist. The senior surgeon (C.J.H.) served as the team leader, responsible for communicating between our team and the local network. During trip preparation, team member credentialing (and vaccination) requirements and necessary equipment were determined. Team members may require international notary of their medical licenses and passports in some countries, which would then be sent to the local country's ministry of health. For equipment, we brought our laryngotracheal reconstruction (LTR) (Table 1), lacrimal probe, bronchoscopy, and adenotonsillectomy sets. Other essential equipment included a pediatric flexible laryngoscope, portable video unit, an assortment of tracheostomy and endotracheal tubes, laryngeal mask airways (LMAs), laryngoscopes, tracheostomy suction supplies, needle cricothyroidotomy kit, intravenous catheters, Foley catheters (in case more accurate vitals were needed in an emergent situation), and restraints. Medications were not needed as they were readily available in Ecuador. Every piece of equipment was carefully packed and inspected by customs agents to ease entry into Ecuador. Administrative coordinators greatly facilitated trip preparation by gathering documents and making travel arrangements.

The perioperative stage was devised next. We created a weekly schedule, with patient screening on the first day, surgeries on the next 3 days, and postoperative direct laryngoscopy with bronchoscopies (DLB) on the eighth or ninth day of the mission. Days 5 through 7 were spent touring other facilities in Quito with the local team, which allowed ample time for education and team building. Emergency airway preparedness was ensured on the first day of each mission by practicing mock codes. All Operation Airway team members were also Pediatric Advanced Life Support (PALS) certified. Patient screening had been initiated at the prior site visit, and these patients were confirmed upon our group's arrival for the formal mission. Patients were evaluated by our pediatric anesthesiologist and/or intensivist to ensure that they were fit for surgery. Surgery was canceled for patients with active infections (examples included upper respiratory infection, scabies, and dengue fever) or active congenital cardiac disease (unless they had an emergent airway). Operative cases were selected (or confirmed if identified during the prior site visit) by the team leader. Up to 2 LTRs were scheduled per day, along with other smaller cases. Functionality of all anesthesia and surgical equipment was verified before the start of the first case. Written and electronic medical records were kept on all patients throughout their hospital courses. Emergency contact information for our team members and our call schedule were given to the local team. Translation services were arranged to assure proper communication between our team and the local population. Often, multiple members of our team were fluent in Spanish.

In the postoperative stage, we relied heavily on the local team for continued follow-up. After the initial postoperative DLB, we provided the local providers and patients' families with clear verbal and written discharge instructions. Continued management occurred via a secure, international electronic medical record, where intraoperative photographs of subsequent DLBs could be assessed. The international electronic medical record was developed with the help of an Israeli software firm. Patient progress was conveyed via secure emails during the months following the mission. Surveillance bronchoscopies occurred at 1 month and 6 months postoperatively, as well as 1 month before the return of the Operation Airway team the next year.

Creating a Sustainable Program

Developing longitudinal care via sustainability is essential when treating these complex pediatric patients. We adopted a "see-know-do" philosophy to ensure that the services we provided could be accomplished by the local providers once we left. Our missions were divided into 3 essential phases. The first mission was designated the "see," or observation, phase. The local providers (surgeons, anesthesiologists, intensivists, nurses, and speech-language pathologists) shadowed our team. The local surgeons observed our team as we performed the initial surgeries. The second mission served as the "know" phase. The local surgeons assisted

Table 2. Summary of Procedures.

Procedure	Total
Direct laryngoscopy with bronchoscopy	23
Tracheostomy	2
T-tube placement	1
Tracheocutaneous fistula closure	1
Open suprastomal granuloma excision	2
Laryngotracheal reconstruction	6
Salivary procedure	5
Dermoid cyst excision	1
Palatal cyst excision	1
Total parotidectomy	1
Lysis of nasal adhesions	1
Videofluoroscopic swallow study	2
Bedside swallow evaluation	40

with the surgeries with close oversight by our team. The other local providers took greater responsibility in their roles, as well. The third mission was the "do" phase. The local surgeons performed the surgeries with our team observing. The other local providers continued to increase their involvement in the care of the patients. Since our missions, the local team in Ecuador has independently performed 3 LTRs successfully.

Education and Training

In addition to the training involving actual clinical care of the patients, significant education and training occurred elsewhere. The local surgeons traveled to Massachusetts Eye and Ear Infirmary to observe airway surgeries and our aerodigestive clinic before we conducted our first mission. During our initial site visit, we conducted a bronchoscopy course. Several lectures regarding the care of pediatric airway patients were given to the local team during each mission. In collaboration with the local Ecuadorian team, we developed a website (http://www.masseyeandear.org/specialties/pediatrics/pediatric-ent/airway/OperationAirway/) to greatly enhance patient education and facilitate dissemination of information to patients and local providers. The website documents the journey of several patients treated by Operation Airway through photos and videos, not only detailing the various steps in their care but also highlighting unique socioeconomic issues that the patients have faced.

Multidisciplinary Care

Comprehensive care of pediatric airway patients mandates a multidisciplinary model. Our airway clinic stateside involves pediatric otolaryngology, pulmonology, gastroenterology, and speech-language pathology. We demonstrated this model to the local team and articulated the interplay between various services via the lecture series. The local surgeons observed this model in action when they visited our clinic, and we reinforced this during each of the missions throughout the preoperative, perioperative, and postoperative phases. Each local provider (surgeon, anesthesiologist, intensivist, and speech-language pathologist) was paired one-to-one with our respective providers. Several nurses were paired with each of our nurses. This personalized, hands-on training reinforced our multidisciplinary model.

Results

Twenty patients ages 4 months to 21 years were included in this study. A summary of the procedures performed during the 3 major missions is outlined in Table 2. In terms of airway surgeries, a total of 23 bronchoscopies, 2 tracheostomies, 1 T-tube placement, 1 tracheocutaneous fistula closure, 2 open granuloma excisions, and 6 LTRs were performed. Many patients suffered from sialorrhea and/or aspiration for which they underwent 5 salivary procedures. These consisted of either parotid duct ligation or 4-duct ligation. Of note, 1 dermoid cyst, 1 palatal cyst, 1 total parotidectomy, and 1 lysis of nasal adhesions were performed. Two videofluoroscopic swallow studies and 40 bedside swallow evaluations were completed by our speech-language pathologist in conjunction with local providers.

Details of the surgical procedures during the 3 major missions are provided in Table 3. The complexity of the patients is readily apparent. One patient had a known syndrome (Crouzon), and 1 patient had Tetralogy of Fallot. Two patients had severe retrognathia, and 1 had oropharyngeal stenosis. Three patients needed central and arterial lines and/or pressors for either sepsis or adrenal insufficiency. The specifics of these events and the systems we developed to prevent them in the future will be detailed in a separate paper. During the first mission, a double stage LTR was performed using an Abouker stent. It is unfortunate that the stent migrated, necessitating an emergent DLB. The same patient developed a tracheocutaneous fistula, which was repaired the next year by our team. From this experience, we developed a new form of airway reconstruction, the 1.5 stage LTR. A 1.5 stage LTR uses a stent in the tracheostoma fashioned from an endotracheal tube, which eliminates the need for an Abouker stent (or other airway stent besides intubating with an endotracheal tube) while maintaining a patent stoma for emergencies.[5] We have not found the rate of tracheocutaneous fistula to be higher after a 1.5 stage LTR, and these results will be reported in an upcoming paper. Primary outcomes measures depended on the procedures that were performed. All LTR patients had been decannulated. All patients who underwent salivary procedures experienced a decreased in salivation. The

Table 3. Details of Surgical Procedures Performed.[a]

Year	Age, y	Sex	Diagnosis	Surgery	Events	Outcome
2013	1	Male	Tracheal stenosis, unrepaired Tetralogy of Fallot	DLB, tracheostomy	None	Needs cardiac surgery and slide tracheoplasty
2013	1	Female	Laryngomalacia, suprastomal granuloma, tracheostomy dependence	DLB, open suprastomal granuloma excision	Adrenal insufficiency	Decannulation
2013	1	Female	Cervical dermoid cyst	Excision of dermoid cyst	None	No recurrence to date
2013	1	Male	Palatal cyst	Excision of palatal cyst	None	No recurrence to date
2013	3	Female	Retrognathia, trismus, nasal adhesions, tracheostomy dependence	Lysis of nasal adhesions	None	Therabite for trismus, possible decannulation soon
2013	4	Male	Subglottic stenosis s/p LTR in 2012, tracheocutaneous fistula	DLB, tracheocutaneous fistula closure	None	Doing well
2013	4	Female	Sialorrhea	4-duct ligation	None	Decreased salivation
2013	5	Male	Sialorrhea	4-duct ligation	None	Decreased salivation
2013	5	Male	Subglottic stenosis s/p LTR in 2012	DLB	None	Decannulated, doing well
2013	5	Female	Deep lobe parotid mass	Total parotidectomy	None	Indeterminate epidermoid lesion on pathology, no recurrence to date, facial nerve intact
2013	7	Male	Bilateral vocal fold immobility, tracheostomy dependence	DLB	None	Plan for cordotomy and possible decannulation
2012	4 (months)	Male	Crouzon, retrognathia, macroglossia, sialorrhea, tracheostomy dependence	DLB, parotid duct ligation	None	Decreased salivation
2012	2	Female	Subglottic stenosis, suprastomal granuloma, tracheostomy dependence	1.5 Stage LTR	Pressors for possible sepsis, central line, arterial line	Decannulated, doing well
2012	4	Male	Subglottic stenosis s/p LTR × 2 in Spain, suprastomal granuloma, tracheostomy dependence	1.5 Stage LTR	Pneumothorax × 2 with chest tubes, pressors for adrenal insufficiency, central line, arterial line	Decannulated in 2013, doing well
2012	9	Female	Subglottic stenosis, cerebral palsy, tracheostomy dependence	1.5 Stage LTR	Central line, arterial line	Decannulated, doing well
2012	13	Male	Recurrent angioedema	DLB, biopsy	None	Lost to follow-up
2012	16	Female	Subglottic stenosis, seizure disorder, tracheostomy dependence	1.5 Stage LTR	Possible seizures, normal head CT	Decannulated, doing well
2011	10 (months)	Male	Benign aryepiglottic mass	DLB, tracheostomy	None	Decannulated, doing well
2011	2	Female	Retrognathia, trismus, suprastomal granuloma, tracheostomy dependence	Open suprastomal granuloma excision, parotid duct ligation	None	Underwent mandibular distraction, decreased salivation, possible decannulation soon
2011	3	Female	Oropharyngeal stenosis from caustic ingestion s/p pharyngoplasty, tracheostomy dependence	DLB, T-tube placement	None	Lost to follow-up

(*Continued*)

Table 3. (Continued)

Year	Age, y	Sex	Diagnosis	Surgery	Events	Outcome
2011	3	Male	Subglottic stenosis, tracheostomy dependence	Double stage LTR	Abouker stent migration requiring emergent DLB	Decannulated, doing well
2011	6	Male	Bilateral vocal fold immobility, tracheostomy dependence	DLB, parotid duct ligation	None	Decreased salivation
2011	8	Male	Posterior glottic stenosis, tracheostomy dependence	Single stage LTR	Adrenal insufficiency	Decannulated, doing well
2011	21	Male	Supraglottic collapse s/p LTR 10 years ago, tracheostomy dependence	DLB	None	Needs supraglottoplasty

Abbreviations: CT, computed tomography; DLB, direct laryngoscopy with bronchoscopy; LTR, laryngotracheal reconstruction; s/p, status post.
[a]Four patients had surgery during 2 subsequent missions.

Table 4. Summary of Lectures Provided.

Year	Total Hours	Details of Lectures
2010 (initial site visit)	12	Bronchoscopy course Modes of mechanical ventilation and ventilatory strategies in neonates and pediatrics
2011-2013	13	Pediatric tracheostomy Surgery for subglottic stenosis Respiratory management ICU care after LTR Aspiration and videofluoroscopic swallow study Pediatric feeding and swallowing disorders

Abbreviations: ICU, intensive care unit; LTR, laryngotracheal reconstruction.

patients who had tumors removed have shown no recurrence to date.

Local providers who have received training include 1 pediatric otolaryngologist, 1 pediatric surgeon, 3 anesthesiologists, 7 intensivists, 16 nurses, and 2 speech-language pathologists. A summary of the lectures delivered is depicted in Table 4. More than 25 hours of lectures covered the breadth of pediatric airway management, and the aforementioned website was created. The details of the surgeries, perioperative/postoperative care, and speech-language pathology concerns were carefully presented in a multidisciplinary fashion.

Discussion

Although international surgical outreach missions with otolaryngology involvement have helped thousands of children with cleft lip and palate, microtia, and chronic ear disease, these missions have yet to treat children with complex airway disorders. Once children are tracheotomized in these same underserved countries, theirs is a dangerous situation due to lack of resources and medical support. In addition, children with laryngotracheal stenosis have no way of being safely decannulated in these settings. Operation Airway was founded to serve these children.

When designing an international surgical mission, quality assurance is of utmost importance. Several cleft missions have described their quality improvement systems throughout the past few decades. Smoot et al[6] stressed that cleft lip and palate missions should never lower their standards because of the relaxed medical-legal climate in other countries, and they outlined a process of patient care and safety, equipment inventory and care, surgical management, and safety for the surgical team. The International Task Force on Volunteer Cleft Missions commented that the major aims of any cleft mission are to provide top-quality surgical service, train local physicians and staff, develop and nurture fresh cleft programs, and make new colleagues.[7] Ruiz-Razura et al[8] emphasized the creation of long-term benefits of Operation San Jose by offering a program to teach local surgeons cleft lip and palate repair techniques and setting up guidelines to organize local surgeons so that they can treat the patients in their own country. Others have reported specifically on anesthesia concerns while performing surgery in underserved countries. Tobias et al[9] reviewed the necessary basic anesthesia supplies needed and discussed issues regarding anesthesia machines, techniques, and monitoring. Fisher et al[10] studied the pediatric anesthesia practices of volunteer medical services abroad and listed the primary barriers to quality improvement as geographic diversity, provider variability, accountability, and event reportability. All of these reports regarding past international surgical missions stress high-quality care and the fostering of good relations, but they warn against operating on complex patients. We have incorporated these well-developed quality improvement surveillance approaches into Operation Airway, adapting them to our approach to complex airway patients.

Of the existing systems used to run international surgical missions, we chose to model Operation Airway on the system developed by Global Smile Foundation. Several of our team members have had experience with GSF missions and have seen its effectiveness firsthand. Global Smile Foundation (formally Medical Missions for Children) produced quality assurance guidelines for surgical outreach programs after more than 20 years of experience providing cleft care to several areas of the globe.[3,4] This gave us the basic framework to divide our mission into the preoperative, perioperative, and postoperative stages, with logical, thorough goals for each stage. With this model in mind, we developed our mission to serve children with complex airway disorders. Consequently, the goals of Operation Airway were to help those children in need, create a sustainable program where the local team can independently provide for their own children, develop an educational curriculum and training program for the local team, and cultivate a collaborative approach to provide successful multidisciplinary care.

During the 3 major missions, Operation Airway surgeons operated on 20 patients ages 4 months to 21 years. Two tracheostomies and 9 open airway procedures were performed. Six of these open procedures were LTRs, and all of these patients have been decannulated. A learning curve existed while training local surgeons. The 1.5 stage LTR was invented after an Abouker stent migrated in 1 of our patients. This also allowed us to treat higher grade stenoses in a similar manner to single stage LTR.[5] We now use the 1.5 stage LTR in certain high-risk patients in the United States, demonstrating the bidirectional collaboration of the Operation Airway approach. Patients in Ecuador were cared for by our team in the same manner as we care for our patients in the United States. During the missions, 3 patients required central and arterial lines and pressors for either sepsis or adrenal insufficiency. In the United States, we rarely need pressors and these additional lines. The children treated in Ecuador likely lack the level of surveillance and full multisystem workups that exist in the United States, leading to instability when challenged with a major surgery. We are now more vigilant for signs of adrenal insufficiency and sepsis when dealing with children in underserved countries.

In terms of other surgeries and procedures, the 5 children who underwent salivary procedures experienced decreased salivation since their surgeries. Four patients underwent surgery for nonairway pathology as well. Surgical missions should be prepared to treat additional pathology when the need arises. Regarding speech-language pathology support, bedside swallow evaluations occurred with regularity, but only 2 videofluoroscopic swallow studies were conducted. Only 1 local facility had fluoroscopy capability, and the machine was located far from our primary facility and functioned only intermittently.

Considerable education and training was accomplished throughout our missions through our unique 2-way model. Many outreach programs are 1-way, where the teaching occurs only while the international team is in the host country. We provide training and exposure to local physicians both during our missions to their country and by bringing them to our home institutions. In our opinion, the local team now possesses the skills necessary to treat children with airway disorders and has already successfully performed multiple LTRs. Since this is the first mission of its kind, it is impossible to compare these results to other groups.

In conclusion, we demonstrate the successful creation of the first mission stemming from a teaching institution with the goal of developing a sustainable, autonomous surgical airway program. We plan to use this same model to expand our services to El Salvador next. It is hoped that other surgical missions will adapt a similar model to treat complex pediatric airway patients in additional underserved countries while upholding the highest standards possible.

Authors' Note

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Army, the Department of the Air Force, the Department of Defense, or the US government. MAJ Rogers and LTC Maturo are military service members. This work was prepared as part of their official duties. Title 17 U.S.C. 105 provides that "copyright protection under this title is not available for any work of the United States Government." Title 17 U.S.C. defines a "United States Government work" as a work prepared by a military service member or employee of the US Government as part of that person's official duties.

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