ORIGINAL RESEARCH

A Market Review of Available Airway Suction Technology

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Abbreviations:
AC: alternating current
DC: direct current
FDA: US Food and Drug Administration
VAC: voltage alternating current
VDC: voltage direct current

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Abstract

Introduction: Airway injuries are the second leading cause of potentially survivable battlefield death and often require airway management strategies. Airway suction, the act of using negative pressure in a patient's upper airway, removes debris that can prevent respiration, decreases possible aspiration risks, and allows clearer viewing of the airway for intubation. The most important characteristics for a portable airway suction device for prehospital combat care are portability, strong suction, and ease of use.

Methods: This market review searched academic papers, military publications, Google searches, and Amazon to identify devices. The search included specific characteristics that would increase the likelihood that the devices would be suitable for battlefield use including weight, size, battery life, noise emission, canister size, tubing, and suction power.

Results: Sixty portable airway suction devices were resulted, 31 of which met inclusion criteria – 11 manually powered devices and 20 battery-operated devices. One type of manual suction pump was a bag-like design with a squeezable suction pump that was extremely lightweight but had limited suction capabilities (vacuum pressure of 100mmHg). Another type of manual suction pump had a trigger-like design which is pulled back to create suction with a firm collection canister that had increased suction capabilities (vacuum pressures of 188-600mmHg), though still less than the battery operated, and was slightly heavier (0.23-0.458kg). Battery-operated devices had increased suction capabilities and were easier to use, but they were larger and weighed more (1.18-11.0kg).

Conclusion: Future research should work to lighten and debulk battery-operated suction devices with high suction performance.

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Introduction

Airway compromise is the second leading cause of potentially survivable battlefield injuries.[1,2] Airway difficulties are typically caused by gross damage to the airway, traumatic shock, brain injuries, or impairment of other airway reflexes.[3] Compromised airways and/or head trauma often require the employment of airway management strategies, which typically include endotracheal intubation, cricothyroidotomy, supraglottic airways, and tracheostomy.[4,5] Blackburn, et al reported that prehospital endotracheal intubation was performed in 68% of patients that received an airway intervention in the prehospital combat setting, with nearly 25% having a combat medic as the highest level of provider recorded in the patient record.[6]

Clearing the airway is vital to airway management, as battlefield injuries can leave the airway clogged with blood, vomit, mucus, foreign bodies, and debris.[7] Airway suction, the act of using negative pressure in a patient's upper airway, removes debris that can prevent respiration, decreases possible aspiration risks, and allows clearer viewing of the airway for intubation.[3] A small mouthful of vomit can cause serious obstructions, and aspirating as little as 25mL of vomit can cause severe pulmonary aspiration injury.[3] In addition to aspiration risks, vomit and blood in the airway complicate interventions, creating the clinical situation of a "difficult airway."[8,9] This is also seen with other common battlefield injury pattens such as facial or airway trauma.[9] It is estimated that six to ten percent of airway obstruction deaths could have been prevented with proper airway management.[3,10]

Most military guidelines recommend suctioning, if available and appropriate, with little to no guidance on proper procedures.[11–13] While it is highly recommended, only approximately one-half of the advanced airways placed use suction in the civilian prehospital

setting.[3] This is likely due to suction devices only being carried by approximately 25% of prehospital providers.[3] The situation on the battlefield is likely much worse, as only 15% of combat medics carry any form of suction device.[14]

The prehospital environment presents many challenges for the use of suction devices, specifically fitting all functions needed into a small, lightweight package. "Portable" suction devices exist, but many are heavy, bulky, require a wall outlet, or otherwise complicate transport on the battlefield. There are very limited data on the usage of suction devices in the field. Military experience suggests that data available would reflect purchases made but not where and when the devices were used.[7]

A survey of medical personnel relevant to combat medicine found that the three most important characteristics of a portable airway suction device are: portability, strong suction, and ease of use.[7] To improve portability of the airway suction devices, the device must be easy to carry, light, small, and perform for an extended period, so information was collected on product weight, dimensions, and canister capacity.[3] Information was collected on vacuum pressure, suction tube diameter, and airflow rate to discover which airway suction devices have strong suction. To allow ease of use in the forward combat zones with limited access to power, information was collected on battery type, battery life, and length of charging time. To assess detectability of deployment in a combat zone, information on maximum noise level was collected. As continuous suction can cause complications, it was determined if devices had intermittent suction capabilities. Information on customer ratings and year of market entry for various available suction system was also collected.

Study Objective

In this study, 31 commercial, off-the-shelf suction devices were assessed for prehospital military use. The search included specific characteristics that would increase the likelihood that the devices would be suitable for battlefield use.[3,7] This included weight, size, battery life, noise emission, canister size, tubing, and catheter.

Methods

Ethics

No human or animal subjects were involved in this market review. Therefore, this review did not require institutional regulatory oversight per institutional policy.

Search Methods

A market review was conducted seeking available suction technology using readily-available sources for public purchasing. Multiple sources were examined for available technology until redundancy was reached and no further discovery of new devices or technology. The reviewed included available suction devices identifiable within academic papers, military publications, Google searches (Google Inc.; Mountain View, California USA), and Amazon searches (Seattle, Washington USA). Google Search finds results by crawling the web for sites, indexing the content of the sites, and then ranking the sites based on relevance to the keywords searched, previous searcher interactions with the site, and how quickly they load.[15] Amazon is an online market in which sellers have posted their products and give Amazon a commission back.[16] Amazon's search engine optimization is based on the keywords searched for and previous transactions of the products, so products that are sold more often are the top results. Google and Amazon web search terms included "portable airway suction," "prehospital airway suction," and "portable suction." Sixty airway suction devices were identified. Suction devices were excluded if they were discontinued (seven devices), if there was little to no information on product specifications (two devices), or if they required a 120-voltage alternating current (VAC) wall outlet (20 devices; Supplemental Table 1, available online only).

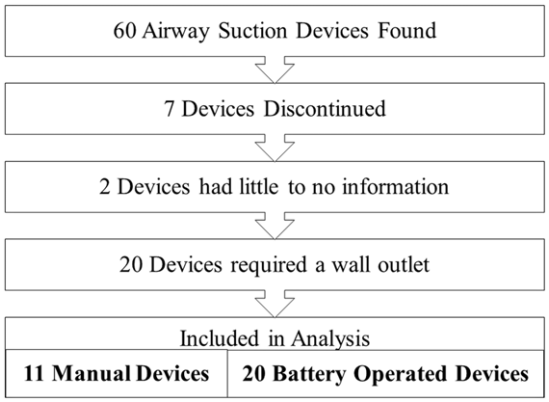

Figure 1. Flow Diagram of Devices Included.

Information provided by manufacturers was compiled. Information was collected from product descriptions, product specifications, manuals, and emails to the manufacturers. Information was compiled on product description, weight (kg), dimensions (cm), canister capacity (mL), vacuum pressure (mmHg), battery type, battery life, charge time, maximum noise level, suction tube diameter, type of suction tip, whether intermittent suction was available, year the product entered the market, and customer ratings and reviews. When available, the devices were cross-referenced with US Food and Drug Administration (FDA; Silver Spring, Maryland USA) documentation, however, since most of these are Class I devices, the FDA clearance process is substantially limited compared to other device technology. Devices were then categorized into manual devices and battery-operated devices.

Results

The internet search yielded 60 airway suction devices, 31 of which met inclusion criteria for comparison (Figure 1; Supplemental Table 1, available online only). The devices were then sorted according to their power supply. Eleven manually operated suction devices were found (Table 1). Twenty battery-operated airway suction devices were compared (Table 2).

Discussion

One of the first steps of airway management is clearing the airway of any debris.[3,17,18] Patient positioning, manually clearing the airway with a finger, or medical suction are commonly recommended ways to clear the airway.[3,11] While adjusting the patient's position can help drain and open the airway, it does not actually clear fluids and materials.[19] Manually clearing the airway is recommended as a last resort due to the threat of infection and digital injury to the medic if the patient clenches their jaw.[3] The effectiveness of the manual method is not established, and the risk of oropharyngeal injury and aspiration is apparent.[20]

While many suction devices exist, no single device is widely used for all military forces. An airway suction device that is compact,

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lightweight, but able to perform all necessary functions is needed. Specifications are not fully established, but De Lorenzo, et al recommended several capabilities for a prehospital suction device that could be carried by medical personnel:[7]

- Weight: <1kg, or <0.5kg for man-pack version;
- Dimensions (including canister): 30 x 10 x 10cm;
- Canister Capacity: 1000mL, or 500mL for man-pack version;
- Flowrate (of vomit): 3L/minute;
- Vacuum Pressure Range (measured at catheter tip): 0-550mmHg;
- Device Operation Time (under no load): 5 minutes;
- Device Operation Time (under maximum load): 3 minutes;
- External Alternating Current/Direct Current (AC/DC) Input Power Range: 120 VAC/12-24 voltage direct current (VDC) nominal;
- Battery Type: rechargeable or disposable;
- Max Noise Level: ≤ 69dBA; and
- Suction Tube Diameter: 1.27-1.91cm.

In Table 1, 11 manual suction devices are presented for comparison. In general, these devices are smaller and lighter than the battery-powered counterparts, but they offer fewer features. When using these devices, the medic must use both hands: one to provide power and one to direct the suction tube, reducing the efficiency of the medic.

The recommended weight for the suction device used in the field is <1kg, or <0.5kg for a version designed for use in the combat medic pack.[7] This is very difficult to create in battery-powered suction devices, which averaged around 4kg. On the other hand, the manually powered devices all weighed under 0.5kg, other than the Enwepoeo Foot Suction Devices. Some of the devices even had weights as low as 0.19kg. If medics are simply looking for a lightweight device that can perform basic suction, manually powered devices may suffice.

In exchange for the lighter weight, many manual devices have lower airflow rates and vacuum pressures. For example, three of the devices have reported maximum vacuum pressures under 200mmHg (EM Innovations Medical's Suction Easy Pump, NestEcho's Handheld Manual Suction Pump, and North American Rescue's Tactical Suction device). Laerdal's V-Vac Starter Kit states it is capable of a peak airflow rate of 70L/minute and the other devices with information on flowrate specify a flow rate of >20L/minute. Unfortunately, air flow rate is not a relevant standard, as it does not consistently correlate to performance in removing viscous fluids and debris.[3,7] In addition, the flow rate and vacuum pressures are also dependent on the ability of the medic working the device. Thus, all the manually powered devices suffer from a lack of realistic performance specifications.

EM Innovations Medical's Suction Easy Pump and North American Rescue's Tactical Suction Device have a similar design: a bag with a suction bulb. While this design offers a lightweight, compact device with large canister capacity (1000mL), both only produce vacuum pressures of 100mmHg, which is much lower than De Lorenzo's recommended capability of 550mmHg.[7] Neither specify the flowrate for their device. Though these devices are small enough to keep in a pack, they have highly limited capabilities.

ASZX's Manual Suction Pump, BZZBZZ's Manual Suction Pump, Curaplex's Manual Suction Unit, Laerdal's V-Vac Starter Kit, Medsource's Manual Suction Pump, Palliative Pros' RespRelief Suction Pump, NestEcho's Handheld Manual Suction Pump, and Fencia's Phlegm Suction Pump Manual include a trigger-like design which is pulled back to create suction with a firm collection canister. While these are reported to be slightly heavier than the previous design, they range from 0.23kg to 0.458 kg, light enough for the military recommendations. They also report higher vacuum pressures than the suction bulb design with maximum vacuum pressure ranging from 188mmHg to 600 mmHg. The devices with information on canister capacity state the capacity between 100-425mL, which is smaller than the recommended 500mL capacity. Overall, these devices weigh slightly more than the suction bulb design, have smaller canister capacities, but have higher suction capabilities.

Due to manual devices producing lower suction capabilities requiring efficiency-reducing two-handed use, De Lorenzo, et al preferentially recommended battery-operated portable suction devices.[7] With the use of a battery, additional specifications must be considered such as battery life, charging time, and maximum noise level.

The addition of a battery and motor adds weight to the design. The weight of these devices ranges from 1.18kg to 11.0kg. All these devices are heavier than the recommended 1.0kg maximum or the 0.5kg maximum for the man-pack version.[7] Many of these devices are too heavy to realistically be carried in the pack of a medic, which already typically weighs over 36kg.[7] The lightest battery-powered device is SSCOR's Quickdraw Alkaline Powered Portable Suction unit, which uses ten single-use AAA batteries in place of the more typical rechargeable lithium-ion batteries. Laerdal's Compact Suction Unit 4 (LCSU 4) and DeVilbiss HealthCare's Vacu-Aide Portable Compact Suction Unit are the next lightest, both weighing approximately 1.5kg. Six out of the twenty battery powered devices analyzed weighed 2-3kg, and eleven of the devices weighed over 3kg.

In addition, the battery-powered devices were larger in size than the manual devices. With these increased dimensions, the canisters had larger capacities. All except SSCOR's Quickdraw Alkaline Powered Portable Suction unit had an option for a canister that was 500mL or larger. Thirteen of the devices had options for a canister capacity of 1000mL or larger.

With the use of battery power, these devices have greater reported suction capabilities. All the devices report a maximum vacuum pressure of 500mmHg or greater, with 13 reaching the recommended vacuum pressure of 550mmHg.[7] In addition, most of the battery-powered devices have reported airflow rates greater than 20L/minute (except for SSCOR's Quickdraw Alkaline Powered Portable Suction unit which has a flowrate of 10-13L/minute). Seven have flowrates greater than 30L/minute. However, as with manually powered devices, air flow rate is not the relevant standard, as it does not consistently correlate to performance in removing viscous fluids and debris.[3,11] While a 3L/minute flowrate for vomit is recommended, the companies offer no information on the flowrate of fluids other than air. Therefore, literature review cannot determine which devices are capable of evacuating vomit at 3L/minute, nor can it be determined which devices are most effective at suctioning up liquids and debris commonly found in the airway.

Future research should work to develop a light and compact battery-operated unit with high suction performance. The heavy weight of currently available battery-operated devices indicates that future efforts to develop a battery-operated military prehospital suction device must investigate ways to reduce weight to be carried in a medic's pack. In addition, research should be conducted to

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determine the flow rate of the airway suction devices in terms of bodily liquids, debris, vomit, and other substances commonly found in the airway other than air. Seeing as the mean average year that the devices entered the market was 2008, recent technology needs to be utilized to develop the most efficient suction device available. The mean year that the devices reviewed entered the market was 2008, indicating that there has been little disruptive innovation within the market.

Efforts by Ahkter, et al to produce an airway suction device designed for use in the combat theater yielded a 1.73kg device capable of producing an airflow rate of 11L/minute.[21] These devices also suggested several tests for common situations encountered in airway injuries in theater. Some modifications to testing include using stimulated particles such as 3D-printed tooth geometries to test suction capability, more realistic vomitus solution, and standardized testing for airflow and vacuum pressure assessment. Overall, they found several important characteristics to improve airway suction in the battlefield, such as larger suction tubes, filters offering less hydraulic resistance, and improved pump designs. They concluded more research is needed to lighten, debulk, and improve suction features of airway suction devices.

In United States' conflicts prior to the 2000s, airway injuries had been the third leading cause of potentially preventable battlefield death after hemorrhage and tension pneumothorax.[22–24] Recent improvements in body armor and medical treatments have changed the battle injury profiles and now airway is a leading contributor to overall mortality.[2] For example, tourniquets were first implemented in a limited fashion in 2005 and nearly universally by 2007 after demonstrating a substantial decrease in mortality due to compressible extremity hemorrhage.[1,3] Improved torso protection has lowered the number of injuries overall, but has caused a relative percentage increase (27%) in primary injuries to the head, neck, and airway.[3,25,26] The net result is a re-orientation of medical priorities with airway compromise, breathing problems, and noncompressible hemorrhage often inseparable as causes of mortality.[2,27] Because of this, future improvements to combat casualty survival will require a comprehensive approach to damage control resuscitation that includes attention to airway, breathing, and noncompressible hemorrhage problems. Ensuring the availability of an appropriately portable and powerful suction device at the point of injury will help address a major gap in airway management. Future research should focus on the relative contribution of airway compromise to battlefield mortality in general, and the mitigating effects of adequate portable suction.

Limitations

This review has several limitations. The main limitation was reliance on manufacturers' and distributors' reports and other information obtained during the search. While such information is useful, it is not typically verified by independent third-parties. Devices that are near-market-ready may not be included due to not being found via internet search. After-market modifications were not considered, such as adding an after-market battery or using alternative suction tubing. Some devices, such as those sold on Amazon, may not be FDA-cleared and therefore cannot be used. Moreover, the FDA clearance pathway for these devices is limited compared to other device technology. Thus, available data from the FDA were limited, if any were readily available. Finally, some of the manufacturers did not provide sufficient detailed information about the products, and adequate third-party information was not available.

Conclusion

This review of 31 commercially available, off-the-shelf airway suction devices focused on potential use in the prehospital combat zones. Manual suction devices offered compact, light-weight design with limited suction ability. Battery-operated devices had higher suction power but weighed significantly more. Future research should work to develop a light and compact battery-operated unit with high suction performance.

Supplementary Materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X22000437

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Device	Manufacture	Weight (kg)	Dimensions (cm)	Canister Capacity (mL)	Airflow Rate (LPM)	Vacuum Pressure (mmHg)	Suction Tube Diameter (mm)	Year Entered Market	Customer Review
Manual Suction Pump	ASZX	"light"	"compact"	unavailable	unavailable	450	4mm and 4.7mm	2020	1 star (1 review)
Manual Suction Pump	BZZBZZ	0.23	18.5x6.4x16.8	300	unavailable	600	6mm and 13mm	unavailable	NA
Manual Suction Unit	Curaplex	0.27	18x22x8	300	>20	450	13mm	2016	2.4 (on Amazon)
Suction Easy Pump	EM Innovations Medical	0.19	27.1x30.2	1000	unavailable	100	9.5mm	1997	3.0/5 (from 2 Amazon reviews)
Foot Suction Device	Enwepoeo	4.2	unavailable	1000	unavailable	600	unavailable	unavailable	unavailable
V-Vac Starter Kit	Laerdal	0.292	34.29x6.35x12.2	425	70	170-380	13.3	Mid-1990s	unavailable
Manual Suction Pump	Medsource	0.454	13x18x8	unavailable	>20	450	unavailable	unavailable	unavailable
RespRelief Suction Pump	Palliative Pros	0.258	18.5x7x16.8	300	>20	0-450	6mm and 13mm	unavailable	unavailable
Handheld Manual Suction Pump	NestEcho	0.458	30x22.9x6.5	100mL	unavailable	188	5.33	2020	3.4 (150 reviews)
Tactical Suction Device	North American Rescue (NAR)	0.21	24.8x9.5x7.6	1000	unavailable	100	unavailable	unavailable	5 (2 reviews)
Phlegm Suction Pump Manual	Fencia	0.425	18x17x6.9	unavailable	unavailable	unavailable	one small one large	2017	3.5 (170 reviews)

Table 1. Manual Suction Units

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Device	Manufacturer	Weight (kg)	Dimensions (cm)	Canister Capacity (mL)	Airflow Rate (LPM)	Vacuum Pressure (mmHg)	Battery Life	Charge Time	Max Noise Level (dBa)	Suction Tube Diameter (mm)	Intermittent Suction	Year Entered Market	Customer Review
Aeros Tote-L-Vac Suction unit	Ohio Medical	7	20.3x30.5x24.1	800 or 1200	36	up to 550	30 min	8 hours or less	unavailable	unavailable	no	2011?	NA
VacuMax Go Portable Suction Machine with Rechargeable Battery	Drive Medical	2.6	31.5x24.9x20.6	800	25	150-530	50 min	less than 8 hours	60				3.5
Eurovac-A Battery operated suction unit	Anand	5.5	37x14x30	500	21	600	90 min	unavailable	55+-3	8mm	no information	unavailable	NA
Eurovac AC/AD Battery Powered Suction Unit	Anand	11	43x22x37	2000	55	600	180 min	unavailable	55+-3	8	no information	unavailable	NA
OptiVac AC/DC Portable Aspirator Model G180	Gomco	5.18	42.7x19.1x23.9	1200 or 1500	30	25-550	180 min	8 hours	60	6.35	constant	2002	4.8
INSTAD Suction Pump	Anand	6	39X22X22	1000	21	600	90 min	unavailable	55+-3	8mm	no information	unavailable	NA
Model 326 M Portable Suction Device Ultra-Lite Aspirator	Impact	5.5	24.1x29.2x12.4	1100	30	0-200 intermittent, 0-550 continuous	120 min	16 hours			yes		
Compact Suction Unit LCSU 4 (300 mL) RTCA Certificate	Laerdal	1.5	18.5x26.2x8.12	300 or 800	30	50-550	45 min	5 hours	69	9.8mm, inner 6.5mm	yes	2012	NA
Suction Unit	Laerdal	3.7	31.5x33x16	1200	30+	80-500+	3 hours 45 min to 30 min depending on vacuum setting	4 hours	57	6.5mm	yes	2001	
LSP Advantage Emergency Portable Suction Unit	Allied Healthcare	4.8	24x19x42.7	800	>30	25-550	75 min	6 hours	60	6.35mm	continuous	2004	NA
Portable Suction Machine Aspirator 50006	Roscoe Medical	2.4	36.3x17.5x21.1	1000	25	530		less than 8 hours	65				
SAM E.P.S. Portable Suction Unit	MG Electric	4.7	33x16.9x34.9	1000	up to 32	0-600	120 min	2.5 hours	46				
QUICKDRAW Alkaline Powered Portable Suction	SSCOR	1.18	27x11x11	300	10-13	80-500	180 min	alkaline battery back (10xAAA)		7.1mm		2006	
VX-2	SSCOR	4.6 kg	43.18 x 22.86 x 13.33	1200	>= 30	exceeds 525	45 minutes		N/A	7.1mm	N/A	2002	N/A
S-SCORT III Portable Suction Unit	SSCOR	3.18 kg	28 x 20.32 x 13.33	1200	>= 30	exceeds 525	30-45 minutes		N/A	7.1mm	N/A	2003	N/A
Suction Pump Aspirator	Veridian	less than 3 kg	36 x 17.78 x 20.32	1000	28	150-550	50-60 min	8 hours	N/A	N/A	N/A	N/A	N/A
Portable Suction Machine	Sunset Healthcare Solutions	2.4 kg	32.6 x 16.18 x 20.62	800/1000/1200	25	50-560	60 min	unavailable	60	NA	N/A	2020	N/A
Vacu-Aide Portable Compact Suction Unit	DeVilbiss Healthcare	1.53 kg	18.4x18.4x17.1	725	27	50-500	45-60 min	5 hours	N/A	N/A	N/A	2004	N/A
Vacu-Aide Quiet Suction Unit	DeVilbiss Healthcare	3	21.1x22.9x30.5	800	27	50-550	60 min	17 hours	55	N/A	N/A	N/A	N/A
7305P Series Homecare Suction Unit	DeVilbiss	2.9	22.9x17.8x20.3	800 or 1200	27	80-550	up to 1 hour	17 hours				2014?	3.5

Table 2. Battery-Powered Suction Units

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