

## SHORT COMMUNICATION

# Portable power supply options for positive airway pressure devices

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**Submitted:** 14 February 2015; **Accepted:** 3 March 2015; **Published:** 29 July 2015

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*Rural and Remote Health* 15: 3499. (Online) 2015

Available: <http://www.rrh.org.au>

## ABSTRACT

**Introduction:** Patients with obstructive sleep apnea (OSA) often face the challenge of how to power their positive airway pressure (PAP) devices when alternating current power supplies are not available in remote areas with lack of electricity or frequent power outages. This article elucidates portable power supply options for PAP devices with the aim to increase alternative power source awareness among medical providers.

**Methods:** A search of scientific databases (Medline, Scopus, Web of Science, Google Scholar, and the Cochrane Library) was carried out on the topic of alternative portable power supply options for treatment of OSA.

**Results:** Scientific databases listed above yielded only limited results. Most articles were found via Google search. These articles were reviewed for alternative power supply options for OSA patients when alternating current is not available. The power supply options in this article include lead–acid batteries (starter, marine and deep-cycle batteries), lithium ion batteries, solar kits, battery packs, backup power systems, portable generators, and travel-size PAP devices.

**Conclusions:** There are several options to power PAP devices with direct current when alternating current is not available. Knowledgeable primary care physicians especially in rural and remote areas can help OSA patients improve PAP compliance in order to mitigate morbidity and long-term complications of OSA.

**Key words:** CPAP battery, PAP backup power, PAP power options, portable CPAP, sleep apnea and power outages, sleep apnea travelers, sleep apnea travelers to remote areas, wilderness and sleep apnea.



## Introduction

Obstructive sleep apnea (OSA) is a chronic disorder of involuntary disruption of airflow in sleep, leading to inadequate gas exchange or cortical arousals, resulting in excessive daytime sleepiness with work/school impairment. Patients with untreated OSA have a higher risk of hypertension, cardiovascular disease and stroke, as well as poor control of chronic medical conditions<sup>1-5</sup>. Positive airway pressure (PAP) devices, either continuous (CPAP) or bilevel (biPAP), are the most efficacious treatment for OSA among different treatment options available<sup>6-11</sup>. A common problem for OSA patients is powering their PAP devices when alternating current (AC) power supplies are not available (eg during power failure or lack of electricity in rural and remote areas or during camping trips, hiking, sailing, or outdoor activities, travelling to remote areas or developing countries, or during military deployment). Currently, medical literature lacks a publication to address this significant problem. The purpose of this article is to provide necessary information on portable power supply options for PAP devices in order to increase knowledge among medical providers, and hence improve healthcare outcomes in OSA patients given the high prevalence of PAP non-adherence (46-83%)<sup>12,13</sup>.

## Methods

A search of scientific databases (Medline, Scopus, Web of Science, Google Scholar and the Cochrane Library) was carried out from database inception to January 2015. Keywords, MeSH terms and phrases searched included combinations of 'continuous positive airway pressure', 'travel', 'electric power supplies', 'sleep apnea', 'wilderness', 'air travel' and 'altitude.' An example of a search on Medline is (((('Continuous Positive Airway Pressure' [Mesh]) AND 'Travel' [Mesh])) OR (('Continuous Positive Airway Pressure' [Mesh]) AND 'Electric Power Supplies' [Mesh])) OR (('Wilderness'[Mesh]) AND 'Obstructive Sleep Apnea'

[Mesh])). A Google search, with similar terms and phrases, was then performed, which yielded about 32 300 hits.

## Results

The search of scientific databases yielded no article on the topic of alternative portable power supply options for PAP devices; however, a few articles were found related to travel and OSA, which are referenced here in this review. Of the hits on Google, the first 20 pages were reviewed for relevance along with manufacturer websites (Table 1)<sup>14-22</sup>.

### *Portable power options*

**Lead–acid batteries (starter, marine, and deep-cycle batteries):** Lead–acid batteries are rechargeable battery systems that provide DC power and when aided by adapters can be used to power PAP devices. Lead–acid batteries can be starter, deep-cycle or marine<sup>23-25</sup>. (Table 2). All of these lead–acid batteries can be used as a source of power to run PAP devices with the help of either an inverter or direct current (DC) adapter or through the cigarette lighter. An inverter can convert the DC power from the vehicle battery to AC power, which can run the PAP device. An inverter can be either directly connected to the battery with clamps or through the cigarette lighter. New PAP machines have a DC output and a DC cable that can be used to run the PAP device by connecting the PAP device and the vehicle battery without the need for starting the engine or inverter<sup>26</sup>. When using a separate battery as the power supply, additional items are necessary, which include an adapter cable and inverter (Fig1).

**Lithium ion batteries:** Lithium ion batteries are used as a part of sophisticated lightweight battery packs, which are easy to use, provide reliable power for 8–24 hours, are moderately cost effective and are allowed by many airlines<sup>27,28</sup>.



**Table 1: PAP device power options based on common PAP device manufacturers\***

Manufacturer/brand	Power options			External battery by manufacturer/inverter needed for battery pack or deep-cycle battery	
	DC port (Y/N)	DC cable available (Y/N)	Integrated battery (Y/N)	Portable battery by manufacturer (Y/N)	Inverter needed (Y/N)
DeVilbiss	Yes	Yes	No	No	Yes
Fisher & Paykel	No	No	No	No	Yes
Philips/Respironics	Yes	Yes	No	Yes	No (most models may connect with DC power cable)
ResMed	Yes	Yes	No	Yes	Yes/No (some models require DC converter or inverter)
Curative Medical (Curasa CPAP)	Yes	No	No	No	Yes
Somnatics (Transcend)	Yes	Yes	No	Yes	No
Human Design Medical (HDM Z1 CPAP)	Yes	No	Yes	Yes	No
Apex Medical	No	No	No	No	Yes
3B Products (RESmart auto CPAP, not available/reference only) <sup>†</sup>	No	No	No	No	Yes
AEIOMed (Everest 3, discontinued) <sup>‡</sup>	Yes	Yes	Yes	Yes	Yes (DC converter)
Carefusion (Puresom CPAP, discontinued) <sup>§</sup>	No	No	No	No	Yes
PMI Probasics (Zzz auto CPAP) <sup>‡</sup>	No	No	No	No	Yes
Puritan-Bennett (Sandman Intro, discontinued) <sup>††</sup>	Yes	Yes	No	No	No

\* Older PAP devices require an inverter to change current from DC to AC. Newer PAP devices may only need power adapters since these can run on DC voltage. DC operation provides twice as much power when compared to the inverter. If a machine has a DC port, it can run without an inverter by simply plugging in the DC power cord that connects with the PAP device and either battery pack or deep-cycle battery. The data was found from the PAP devices' manufacturer product information sheets and online resources. All features need to be verified prior to purchasing a PAP device as features change and may become outdated.

<sup>†</sup> Listed on 3B's website but not available or listed as 'reference only' on online PAP device websites.

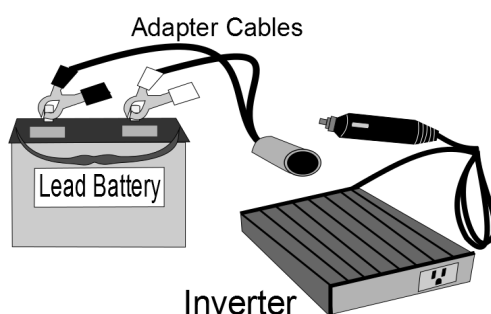
<sup>‡</sup> Could not locate AEIOMed's website; different online merchants report the product 'discontinued'.

<sup>§</sup> Carefusion website does not list CPAP products; however, this is searchable on other country websites; different online merchants report it 'discontinued'.

<sup>‡</sup> Listed on PMI website, but online merchants report it 'no longer available, out of stock'.

<sup>††</sup> Not listed on Puritan-Bennett website; different online merchants report it 'discontinued'.

CPAP, continuous positive airway pressure. DC cord, helps connect with battery pack or deep-cycle battery if it has black and red alligator clips to attach with battery terminals. (Determine for your PAP device if intervening inverter is needed or not). DC port, connects with deep cycle battery or battery pack with DC cord. Integrated battery, allows PAP machine to run on AC current in during power outages.



**Figure 1:** Example of a lead–acid battery power supply setup: lead–acid battery (left), adapter cable (middle), and inverter that connects to the PAP device (right).

**Table 2: Portable power supply options for PAP devices, by major and sub-categories**

Lead–acid batteries			Lithium ion batteries	Backup power System	Portable generators	Solar batteries
<i>Starter (car battery)</i>	<i>Deep-cycle (recreational vehicle/boat house)</i>	<i>Marine (deep sea)</i>				
Shorter duration (up to 8 hours) Brief large current to ignite an engine Can be used through the cigarette lighter switch or outside of the car with the help of the inverter Less expensive than deep cycle or marine battery, as low as US\$20–50 Requires lead–acid battery charger	Longer duration (8–24 hours) Sustained current Slightly more expensive than starter batteries (usual range US\$40–100) Requires lead–acid battery charger	Longer duration like deep-cycle battery (8–24 hours) Provide both short bursts of high current and long-duration sustained current Requires lead–acid battery charger Can be expensive (US\$100–200)	Lightweight Longer duration (8–24 hours usually) Expensive (US\$150–600) Airplane compatible	Built-in battery, DC port and inverter Electronics as cell phone can be plugged in Expensive; price varies depending upon size Solar batteries available for charging	Most are noisy Performance can vary depending on the quality Operated by fuel and gas Not as portable as other power supplies due to large size Price varies depending upon the size	Lightweight Need sunlight for operation Expensive; price varies depending on size

**Backup power systems:** Backup power systems (uninterruptible power source (UPS), standby generators, DC power systems) are often used in the event of a power outage; however, these can be extremely heavy. Portable backup power systems are relatively light and thus easier to transport, but they can be expensive<sup>29,30</sup>.

**Portable generators:** Portable generators that run on gas or other types of fuel are another power supply option. Their price varies widely, depending upon the size of the unit. A significant limitation is that they are cumbersome to transport and produce a significant amount of noise and exhaust.

**Portable travel machines:** The two most commonly listed lightweight travel size machines include Transcend CPAP and HDM Z1 CPAP. Some newer models of Transcend machines have overnight battery options, which can be recharged in a few hours using a solar charger. These battery packs can run the Transcend machine when the AC current is not available. HDM Z1 CPAP is the lightest machine available in the market and has a power shell integrated battery pack in case of power failure. This battery can provide eight plus hours of runtime in 14 cm of water<sup>31,32</sup>.



**Public transport:** When traveling by air, train or at sea, electrical outlets can be found for operating PAP devices. Power outlets may not be present on every seat, and voltage requirements may be different as well. Hence, passengers may need an adapter to convert the voltage depending upon the carrier. According to the US *Air Carrier Access Act 2009* (part 382.11), passengers can use their PAP devices on airplanes as long as they provide a document of medical necessity, advance notification to the carrier, and manufacturer labeling indicating Federal Aviation Administration requirements for medical portable devices<sup>33</sup>.

**Solar kits:** PAP devices can be charged with compact solar panels in a variety of solar kits, which usually comprise a solar panel, attached charge storing battery device with integrated AC and DC outlets. These power systems can be expensive, depending upon the voltage capacity and desired power needs<sup>34</sup>.

## Discussion

Sleep deprivation can be debilitating among CPAP users in remote areas with lack of electricity or in areas of frequent power outages. Their inability to function optimally in such situations could cause side effects of untreated OSA, including hypersomnia as well as increased risk of traffic accidents, high altitude pulmonary edema, and sudden cardiac death<sup>35-37</sup>.

Most OSA patients require nightly PAP therapy for alleviation of daytime symptoms except mild OSA patients or patients who do not have significant daytime symptoms or comorbidities. Therefore, patients with mild OSA may not need a PAP device if they are going for a short trip or if lack of electricity is only for a short duration. However, it is advisable even for mild OSA patients to use PAP every night if they are going for long trips and/or to high altitudes<sup>7,36</sup>.

OSA patients who have underlying chronic respiratory diseases and are dependent on supplemental oxygen with PAP therapy may need to take their portable oxygen concentrator with them when travelling by air or going to remote areas at high elevation as altitude exposure may exacerbate hypoxemia. The *Air Carrier Access*

*Act* does allow portable oxygen concentrators for air travel; however, it is recommended for patients to confirm with their airline as well as follow country-specific guidelines for people with respiratory diseases<sup>38</sup>.

Portable PAP device power supplies (aside from generators) are generally quiet. In general, deep-cycle and marine batteries can operate a PAP device for longer periods of time than car batteries. More sophisticated portable power systems made of lead-acid batteries can run a PAP device for up to 54 hours and may need charging once a week. The price for these portable systems can be US\$100–200 compared to a simple deep cycle battery, which costs less than \$50. Like the deep-cycle batteries, the newer lithium ion portable battery packs are also an excellent option given the extended duration of backup power for up to 24 hours. Emergency backup power systems with integrated batteries are also a good option to use at home; however, these have a high variability of backup power, so each device would need to be reviewed for duration of power. Lightweight solar kits usually provide only a few hours of power, except in the case of larger kits, which can be heavy and expensive. Newer portable CPAP machines are a good alternative to backup power systems. A drawback is their relatively higher price (US\$400–600), and they are usually not covered by all insurance companies. It should be noted that PAP devices are recommended to be used without the humidifier when they are being operated with DC power, since adding the humidifier will drain the battery faster.

There are limitations to this study. First of all, there are no identified reviews on the topic in the literature, so this information was obtained from PAP device instruction manuals, PAP device manufacturer websites and other online resources that are referenced herein. The authors made every attempt to obtain the majority of information from PAP device manufacturers as this was the most reliable source of information. The information contained in this article will help improve patient care and provides both providers and patients with current information on what is necessary to power a PAP device when there is no alternating current power supply available. Table 3 summarizes lightweight PAP devices.



**Table 3: Lightest CPAP/biPAP devices (up to 1 kg)**

CPAP/biPAP	Weight (g)	Operating pressure range (cmH <sub>2</sub> O)	Auto pressure adjustment	Auto altitude adjustment	Reports compliance and/or AHI	Battery powered	Noise level (dB)	DC port (connect battery pack or deep-cycle battery)	Integrated battery (can run on AC)
HDM Z1 CPAP	283	4–20	Yes	Yes	Yes	Yes	26	Yes	Yes
Transcend CPAP	426	4–20	Yes	Yes	Yes	Yes	26.6–29	Yes	No
Pobasics Zzz Auto CPAP <sup>†</sup>	798	4–20	Yes	Yes	Yes	No	32	No	No
S9 Elite/Escape CPAP	835	4–20	Yes	Yes	Yes	No	26	Yes	No
Apex XT Auto CPAP	848	4–20	Yes	Yes	Yes	No	28	No	No
System One REMStar 60 SE CPAP (base model)	907	4–20	No	No	Yes	No	<30	Yes	No
S9 VPAP auto bilevel	834	4–25 (IPAP) 3–25 (EPAP)	Yes	Yes	Yes	No	26	Yes	No

AHI, apnea–hypopnea index (AHI). biPAP, bilevel positive airway pressure. CPAP, continuous positive airway pressure. EPAP, expiratory positive airway pressure. IPAP, inspiratory positive airway pressure.

<sup>†</sup> Listed on PMI website, but online merchants report it ‘no longer available, out of stock’.

## Conclusions

Currently there are several portable power supply options available for PAP devices, including lead–acid batteries, portable battery packs, and battery-operated lightweight CPAP machines. To improve PAP adherence, it is vital for medical providers, especially in remote and rural settings to educate their patients about portable power supply options when there is no AC power supply available.

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