

IMPROVISATIONAL WILDERNESS TECHNIQUES

Retrieval of Additional Epinephrine From Auto-Injectors

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Anaphylaxis is a challenging condition for any austere environment. It is unpredictable, has sudden onset and a high fatality rate, and is responsive only to epinephrine, a prescription medication. The Wilderness Medical Society has formally recommended that non-medical providers working in austere environments be trained to administer epinephrine. Medical providers frequently prescribe auto-injectors for this purpose due to their ease of use by nonmedical providers. However, auto-injectors have limitations in the wilderness environment, particularly due to their single-dose (or at most 2-dose) design. This paper describes an austere environment technique for obtaining multiple additional doses of epinephrine from auto-injectors that have already been used as designed.

Key words: anaphylaxis, epinephrine, auto-injector, wilderness, wilderness medicine

Introduction

Anaphylaxis, defined by the Second Symposium on the Definition and Management of Anaphylaxis as “a serious allergic reaction that is rapid in onset and may cause death,”¹ is one of the most dangerous conditions that can be encountered in the wilderness. Its onset is sudden, it may occur in patients without known allergies, it has a high fatality rate if not treated, and it is responsive to only one medication (epinephrine), which in the United States and many other countries is only available by prescription.

The Wilderness Medical Society has recommended that nonmedical providers whose work requires them to deliver emergency medical care be trained to administer epinephrine.² Many authorities and studies favor auto-injectors as the preferred device for administering epinephrine.^{3–5} However, available auto-injectors have some limitations for the wilderness environment: they are expensive, bulky, temperature labile, and are designed to provide only a single dose of epinephrine (or with a few devices, 2 doses).

This paper describes an austere environment technique that salvages as many as 4 additional doses of epinephrine from a single auto-injector after the unit has been used in standard fashion.

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Review of Epinephrine and Administration Devices

The accepted treatment for all forms of anaphylaxis is epinephrine. A complete review of the pharmacology and indications for epinephrine is beyond the scope of this study, but is covered well elsewhere in the medical literature.^{1–3}

Current standards dictate that epinephrine only be injected intramuscularly or, in very severe cases of anaphylactic shock, intravenously; subcutaneous epinephrine is no longer considered appropriate for any variation of anaphylaxis.^{1,2}

The response of anaphylaxis patients who successfully respond to epinephrine can take 1 of 3 forms. In the uniphasic pattern, a single episode of anaphylaxis responds to a first dose of epinephrine. In the biphasic pattern, which occurs in about a third of episodes,⁶ the patient relapses back into anaphylaxis and requires a second dose of epinephrine. In approximately 5% of biphasic cases, a protracted pattern appears, with multiple or ongoing relapses.

The most frequent tool used by non-healthcare providers to administer epinephrine is an auto-injector. The most frequently utilized auto-injector in the United States is the EpiPen (Figure 1). In some states, even certain types of Emergency Medical Service healthcare providers are only permitted to administer epinephrine by an auto-injector.⁷



Figure 1. Post-2010 EpiPen auto-injector demonstrating new body, blue safety cap, and orange needle end. Note that this specific auto-injector is an EpiPen Jr. Epinephrine salvage techniques are the same for both EpiPen and EpiPen Jr formulations. Also note that this EpiPen has not been used (the orange shield has not extended, compared with the extended orange shield illustrated in Figure 4). The salvage techniques in this article should never be tried on an unused EpiPen (one whose orange shield is not extended), such as the one illustrated here. Photograph courtesy F. Baty.

Importantly for wilderness applications, a single dose of epinephrine is frequently not enough to manage even a single episode of anaphylaxis, as many episodes are biphasic or protracted. Because most auto-injectors are single-dose tools, the capability for multiple dosing is extremely unlikely without carrying multiple injectors. Access to multiple injectors is often unfeasible in the wilderness setting because of cost, size, or lack of

preplanning. Planners of expeditions or trips need to make a difficult decision regarding how many auto-injectors to carry, or need to use vial-based epinephrine for additional doses. Field treatment of protracted anaphylaxis in the wilderness is extremely difficult and evacuation can be complex; larger supplies of epinephrine may be required to provide subsequent dosing of epinephrine for even a single patient.⁵

In light of the frequency of biphasic or protracted patterns of anaphylaxis, EpiPens are now generally sold as a 2-pack. Even with this retail decision, the 2-pack is often separated for convenience and to facilitate storing EpiPens in several locations. As a result, often only 1 is still available when needed.

In October 2010, Dey Pharmaceuticals introduced a new auto-injector device for the EpiPen product (Figure 1). This new auto-injector substantially changed its shell, included different coloring, added a sheath protecting the user from the exposed needle after drug administration, and altered its delivery system. It remains a single-dose device.

Although the earlier style auto-injectors are being replaced in the market by the updated model, it seems reasonable and prudent to assume wilderness medicine providers practicing in remote or resource-poor environments will continue to encounter examples of the original model for some time. That is especially true given the high cost of EpiPens and studies in the medical literature showing that EpiPen epinephrine maintains 63% of its original potency 10 years after its manufacture.⁸ In addition, it appears that other countries (such as the United Kingdom) utilize devices or variations that still market the pre-2010 Dey auto-injector body, even after the 2010 transition to the new body.⁹

For the last 20 years, Wilderness Medicine Outfitters (WMO) has been teaching a method for accessing additional doses of epinephrine from EpiPens. This technique has been expanded to include the new EpiPen devices introduced in 2010, as well as adaptations for Adrenaclick and Greenstone auto-injectors. A third dose from Twinject has been taught since 2006.

The authors recognize others may have developed similar techniques during this period. In addition, some institutions, such as Roane State, have more recently developed adaptations to the technique originally taught by WMO. The technique is potentially life-saving for patients who are having a biphasic or protracted anaphylactic reaction. The WMO has on record a case of a physician who reversed a biphasic anaphylactic reaction using this technique when no further auto-injectors or other sources of epinephrine were available after the first dose of an EpiPen auto-injector. In 2012, a WMO alumnus experiencing protracted anaphylaxis

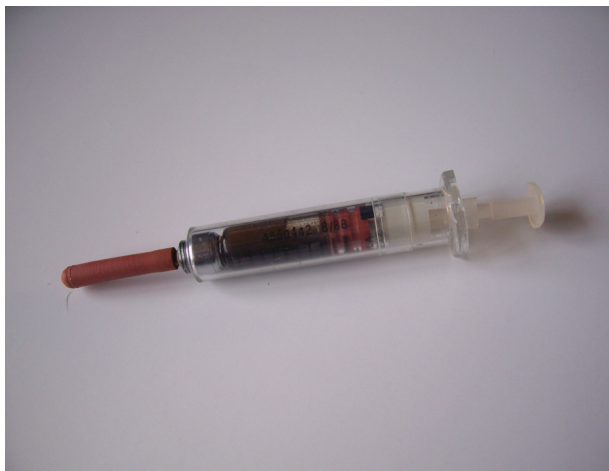


Figure 2. Particulate matter. Compare this image of a 24-year-old Anaguard with particulate matter (do not use auto-injectors with fluid looking like this) to the image in Figure 3 of EpiPen carpules with color change but no particulate matter. Manufacturer recommendations discourage use of discolored fluid, but no evidence can be found of hypothetical or actual adverse effects from using discolored epinephrine. Photograph courtesy C. Weil.

successfully administered multiple doses of epinephrine from her single-dose Greenstone auto-injector using this technique.

Why so much additional epinephrine is included in single dose auto-injectors is a common question. One author (C.W.) contacted Dey Pharmaceuticals, manufacturer of EpiPens, with this question. Their answer was that the extra epinephrine helped keep the delivery system stable, but they did not answer subsequent queries as to how extra epinephrine specifically stabilized the delivery system.

Before considering all techniques described, readers are warned: this technique is not approved either by the Food and Drug Administration or by the manufacturer. It is offered as an ad hoc emergency adaptation that may be needed in an austere or wilderness operational environment when insufficient resources are available to treat anaphylaxis using standard techniques. It does entail some risk to bystanders and operator.

Never rely on this emergency method for anticipated management of anaphylaxis. Buy new auto-injectors before old ones expire, and carry sufficient auto-injectors to handle anticipated anaphylaxis cases without relying on retrieving additional epinephrine using this method.

Manufacturers recommend against use of epinephrine that is cloudy in density or contains particulate solution (Figure 2). Epinephrine fluid naturally changes color over time from clear to yellow to brown (Figure 3) with

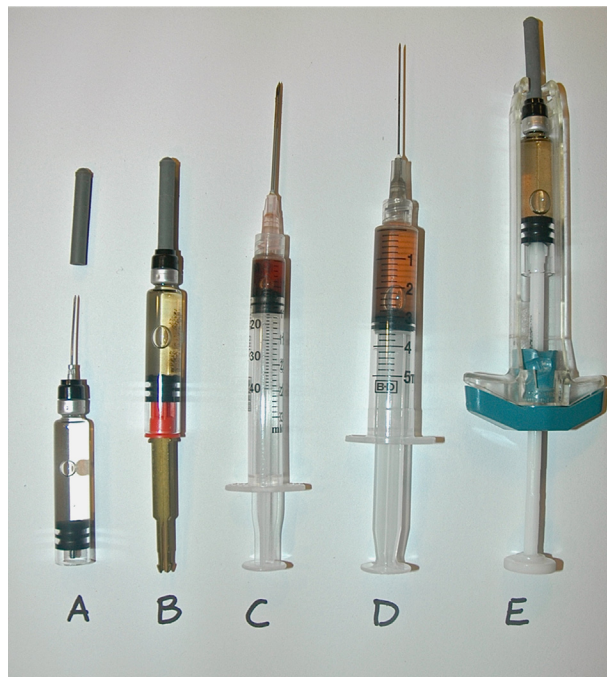


Figure 3. (A) Pre-2010 EpiPen carpule before transfer to syringe without brass plunger. (B) Pre-2010 EpiPen carpule with brass plunger. (C) A 3-cc syringe with transferred epinephrine. (D) A 5-cc syringe with transferred epinephrine. (E) Original EpiPen carpule (pre-2010) loaded into Tubex. Note various degrees of fluid discoloration, from completely clear in carpule A to significantly discolored in carpule C, as well as particulate matter in carpule B. Epinephrine color changes naturally from clear to yellow to brown over time, but there is no known evidence of change in medication efficacy specifically due to or represented by color change.^{8,10} Particulate matter, as in carpule B, would be a contraindication to use. Photograph courtesy S. Hawkins.

no known change in efficacy or safety.¹⁰ However, no evidence, including a study on expired EpiPens,⁸ demonstrates that discrimination based on fluid color is clinically significant. Note here that we differentiate “cloudy” (fluid containing particulates or density changes) from “discolored” (fluid that has merely changed color but not consistency).

Only persons with safe bladecraft training should attempt this technique. All cutting should be done only with locked or fixed blade on a hard stable surface, keeping edge and point away from body parts. Whichever tools you use in this practice should be the same ones you intend to carry and use should you be forced in an emergency to perform this procedure in the field. Always wear eye protection throughout this technique. The needle end of the auto-injector should never be pointed toward the operator or bystanders.

The auto-injector must have been discharged before disassembly. A nondischarged auto-injector has a tightly



Figure 4. Retrieved material from auto-injectors. From left to right: pre-2010 EpiPen carpule, pre-2010 rubber needle cover, post-2010 EpiPen carpule, auto-injector springs (2 types), Twinject syringe with yellow clip. Photograph courtesy C. Weil.

compressed spring (Figures 4 and 5). Some practitioners have attempted disassembling nondischarged EpiPens. These attempts usually result in shooting the needle, carpule, and spring a considerable distance with significant force and potential for serious injury. After the auto-injector is fired, the spring almost doubles in length, relieving much of its potential energy. Bear in mind that after discharge, the spring is still under some force in all brands of devices. This residual force will more gently pop out the parts of the auto-injector as it is disassembled.

Remember that EpiPen Jr auto-injectors have half the epinephrine of adult auto-injectors. (The technique described here may in fact allow for more accurate weight-based dosing in pediatric patients in subsequent doses.)

This technique should be attempted, and then routinely practiced, during leisure or classroom time before an emergent need for accessing additional epinephrine. One suggestion is to practice retrieving the epinephrine from any expired auto-injector that is otherwise being discarded.

Accessing Epinephrine From Post-2010 EpiPens

The needle assembly in the new style auto-injector (an oval tube shape) is somewhat more complicated than the older style pen (a circular tube shape). There are practical advantages to the change in design as the needle of the newer device, after injection, is protected with a hard plastic cover, colored orange (Figure 6). The new style

auto-injector has the white spring apparatus at the top of the pen with a blue safety cap, and the carpule is in an orange assembly at the other end (Figure 1).

To access the carpule assembly, the white plastic leaf spring mechanism must be removed. It is attached to the translucent housing by 3 triangle-shaped plastic pins molded into the housing. There are 2 basic ways to remove it, labeled here as the WMO Method and the Roane State Method.

WMO METHOD

- This removal method starts by making a 1.25-inch cut in the center of both flat sides, starting at the end with the blue safety cap and moving toward the needle (Figure 7).
- Pliers can now wiggle and remove the white plastic end plug. This can be done by firmly holding the device and placing 1 nose of the pliers into the hole in the center of the white plastic end plug and grasping the outside of the device with the other nose of the pliers (Figure 8). Do not peel back the cut flaps of the rear end more than 50% or you will risk deploying the spring with uncontrolled force (Figure 9).
- Pulling and wiggling frees the spring assembly from the case, allowing the spring to expand in a controlled fashion and causing the white end plug to be pushed out of the housing with the spring (Figure 10). The syringe can now be pulled out.



Figure 5. Insert knife edge between rear and sheath of unit. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.

Roane State Method

- This removal method involves releasing the top by cutting the translucent plastic cover between the white plastic triangles of the spring assembly and the spring end of the cover. Care must be taken when the spring is released, as the stored energy represents a significant force. An article of clothing, a sleeping bag, or other material should be placed near the end of the auto-injector to blunt any unexpected release.
- Peel off the plastic cover that contains the instructions for the device's use and begin cutting the plastic housing.
- As the plastic housing is cut, it will eventually start to shift, meaning the spring mechanism is nearly free from the housing. When it does finally break free (Figure 5), the spring will launch the housing with some force.
- Once the housing is off, the process is the same as with the first technique.
- With the spring mechanism removed, turn the housing so the orange flat end is against the hard surface and push, allowing the carpule assembly to fall out of the housing (Figure 11).
- To remove the carpule from the orange assembly, it must be released from the orange plastic. There are 2 long slots, 1 on each side of the assembly. In each narrow slot is a white plastic arm. These arms hold the carpule firmly in the assembly. Pinching over the white arms allows the carpule to slide out easily (Figure 12).
- Looking at the open end, the one away from the needle, there will be 2 cylinders connected by a male-female arrangement: the one is white (with the male end), the other is black (housing the female



Figure 6. In the post-2010 EpiPen, an orange shell slides out after needle use as illustrated here, protecting the user from the needle during further manipulation (until entire shell is opened and removed, releasing carpule and needle). Photograph courtesy F. Baty.



Figure 7. Demonstration of site to initiate cutting using the WMO method on a post-2010 EpiPen. Still photograph courtesy of Seth C. Hawkins, from video courtesy of David Fitzpatrick and Caleb S. Varnadoe.

connection). Separate these 2 cylinders. This must be done carefully to avoid spilling the epinephrine. [Figures 9](#) and [13](#) demonstrate the carpule removed from the opened auto-injector shell.

- The carpule and its attached needle can now be used to administer additional doses of medication (see “Administering Additional Epinephrine” section below).

The full technique for accessing additional epinephrine from post-2010 EpiPens is shown in online [Supplementary Video 1](#).

Accessing Additional Epinephrine From Pre-2010 EpiPens

The most commonly encountered auto-injector device is the single-dose EpiPen, and the pre-2010 model will

only slowly be replaced by the newer model. The construction of these earlier units makes disassembly and access to the residual drug somewhat easier than with the later auto-injectors; however, the lack of a safety cover over the deployed needle necessitates extra caution be used. Two methods are available: the WMO method uses pliers, and the Roane State method uses a knife.

WMO METHOD

- After the device has been fired, hold it firmly on a hard surface with a fist around the body of the tube.
- Position the end originally holding the gray safety cap over the surface edge.
- Firmly grip the safety end with pliers and bend it down as if to snap it out of the tube.



Figure 8. Pry back sheath less than 50%. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.



Figure 9. Tools used to remove the carpule, the carpule itself after removal, and the opened auto-injector shell of a post-2010 EpiPen. Photograph courtesy F. Baty.

- Repeat this firm up-and-down movement several times and the spring and end plug will be released.
 - Remove the outer label. The interior components of the device are now visible through the translucent housing. This gives a reference point for the location of the cut to make on the device's body. The carpule containing epinephrine can be seen, and to the rear of that is the plunger and plastic spring housing, which remains under tension after discharge.
- ROANE STATE METHOD**
- In a wilderness setting, a knife may be more readily available than pliers. If a knife is the only tool available, the technique can be modified to use it.
 - First make sure the device has been fired, which is confirmed by seeing the exposed needle.
 - Cut the translucent outer plastic case over the white spring housing, taking care to aim the spring-loaded end into a suitable surface such as a rolled sleeping



Figure 10. Pliers grip rear of unit. Photo credits: Caleb S. Varnadoe and David Fitzpatrick.



Figure 11. Push the injector unit out against a solid object. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.

bag or jacket. Once the body is cut to the point where it no longer contains the tension, the spring will deploy, ejecting the end of the device.

- The spring is released by either the Roane State method or WMO method.
- After removal of the spring, the carpule of epinephrine can be gently released by gravity when the remaining shell is turned needle up.
- At the rear of the carpule is a rubber plunger, which is moveable. Remove carpule by gently pulling brass plunger fittings.
- Carefully turn rubber needle proctor to loosen and remove. Point needle straight up, pulling carefully so as not to pull rubber out of the glass barrel tube until the rubber plunger is close to the end of the glass barrel, replacing the injected epinephrine with an air bubble. Be careful, because pulling the rubber plunger all the way will allow the epinephrine to be spilled and lost.

- The carpule and its attached needle can then be used to administer additional doses of medication (see the “Administering Additional Epinephrine” section below for instructions).

The full technique for accessing additional epinephrine from pre-2010 EpiPens is shown in the online [Supplementary Video 2](#).

Accessing Epinephrine From Other Auto-Injectors

Disassembly of the Twinject is not difficult, since it is designed to make at least one additional dose available.

- Hold red needle end while injector body is unscrewed 2 and a half turns. Holding the red needle end while turning the body seems to minimize possibility of accidental needlestick.



Figure 12. Plastic “wings” on each side of the injector unit must be depressed to release the unit. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.

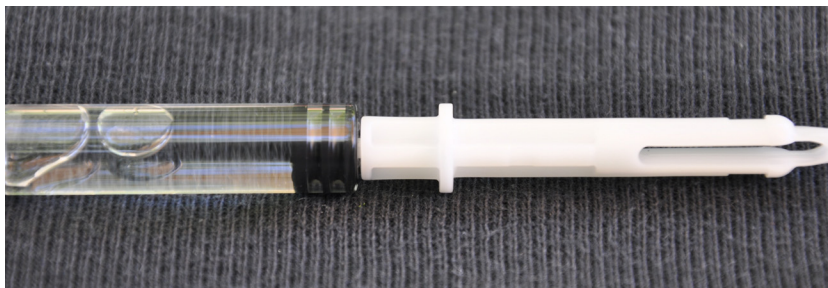


Figure 13. Note air bubbles forming in syringe, and black plunger at edge of glass. That would be the appearance after plunger is drawn back to administer additional doses. An unused EpiPen would also have this appearance (black at end of glass, white entirely outside of glass) but would not have air bubbles in the carpule. Photograph courtesy F. Baty.

- Once the red cap and spring are free, lift them off and set aside.
- Withdraw the blue needle hub with syringe from injector body. Look at where the rubber plunger is in the glass tube and mark (or take mental note if marking is not feasible).
- Remove yellow or orange (older models) clip from plunger end to access second dose (Figure 4).
- Additional doses require pointing the needle straight up and pulling the plunger back down to the end of the glass, drawing in more air. Reverse the syringe until the needle points straight down toward the thigh. The bubble of air will act as an auxiliary plunger/pusher.

The AdrenaClick and Greenstone auto-injectors require pliers to break loose the cap on the needle end, unscrewing the cap before withdrawing the syringe. There will be no clip to remove; otherwise, the procedure is the same as for the Twinject. Place syringe back in the device tube or carry tube for safe keeping.

The full technique for accessing additional epinephrine from non-EpiPen auto-injectors is described in the online [Supplementary Video 3](#).

Administering Additional Epinephrine Retrieved From Auto-Injectors

The various techniques described above result in the carpule and needle being freed from the auto-injector shell. This section explains how to administer the epinephrine from the freed carpule.

Since the design of the Dey auto-injector is constructed to deliver a single dose of epinephrine, merely pushing the plunger further into the syringe will not deliver an additional dose; one cannot push it further because a flange on the white part of the plunger prevents its travel any deeper into the syringe. In an unused auto-injector, the black part is nearly at the end of the glass and the white part is actually outside the

glass. When activated, the spring pushes the white rod/white cylinder against the black, forcing the black into the glass and thus forcing the designed dose of epinephrine through the needle (Figure 14). To access the remaining epinephrine after the auto-injector has been used, a means must be found to push out more epinephrine without pulling the black plug out of the glass.

Two methods for accomplishing this can be employed, as follows.

METHOD 1

- Raising the needle into an upward position, draw enough air into the syringe to allow the plunger to return to its original position with the first edge of the black plunger just even with the end of the glass (Figure 15). This will introduce air into the carpule (Figure 13).
- Inject, pushing the plunger until it is stopped by the glass. This ensures the correct dose of the drug will be injected. Subsequent doses can be delivered in a similar manner.

Method 1 is demonstrated in the post-2010 epinephrine retrieval online [Supplementary Video 1](#).

METHOD 2

- Lever the white component of the plunger out of the syringe (being careful not to dislodge the black part of the plunger).
- Turn the white component of the plunger around 180°, insert it into the carpule, and inject in a more traditional manner.

Because the syringe does not have graduated markings indicating milligrams or cubic centimeters on the glass, some marking system or approximation must be made to insure against either overdosing or underdosing.



Figure 14. Distance from the back of the black plunger and the collar on the white plunger arm is 1 stroke length, ergo a 1-unit dose. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.

Wilderness EMS Adaptations for Auto-Injectors

This technique may have implications not only for non-healthcare providers or wilderness enthusiasts, but also for persons involved in formal Wilderness Emergency Medical Systems (WEMS) who respond to wilderness areas to provide care or who would like to teach these techniques. It is important for WEMS personnel to be aware of this field adaptation for possible use during formal emergency response, in case the epinephrine they should all carry becomes damaged, diverted, or exhausted.

There are some technical adaptations that can be made using equipment potentially available to WEMS responders but not in standard first aid kits. For example, the plunger in the pre-2010 EpiPen has a threaded piece of metal at its center. This thread appears to be universal for EMS needle mount systems, such as Tubexes (Figure 3).

That may facilitate intramuscular injections by providing a sturdier system and more carpule protection.

As another example, epinephrine may be withdrawn into a small syringe and dispensed using that syringe and a new, sterile needle. If available, this is a preferable method of administering the remaining drug, as it allows for precise dosing and the use of a new needle with each administration (Figure 3).

Conclusions

In emergency cases of anaphylaxis encountered in the austere, resource-deficient, or wilderness environment, it may be lifesaving to be able to retrieve additional doses of epinephrine from auto-injectors that are otherwise intended only for single dosage. This paper has described a series of techniques, confirmed by practice



Figure 15. Carpule in place ready for injection shows air bubble above the fluid line. Here, cardboard is simulating the subject's injection site. Photo credits: Caleb S. Varnadoe, David Fitzpatrick.

and expert consensus of the authors, which are proposed as the safest and most effective way to accomplish this salvage retrieval. It is important to remember that these techniques are presented as emergency adaptations to a resource-deficient situation, and should not be used prospectively as an anticipated technique to manage biphasic anaphylaxis, protracted anaphylaxis, or multiple anaphylactic patients.

Disclaimers

Carl Weil is the founder and owner of Wilderness Medicine Outfitters, which teaches these techniques. He also served as an educator consultant for Verus Pharmaceutical from 2006 to March 2008. He is the founder and director of AnaphylaxisEducators.com and was recently named a Master Fellow by the Academy of Wilderness Medicine with specialization in anaphylaxis. David Fitzpatrick serves as an instructor for Wilderness Medicine Outfitters. Fred Baty and Bryan Rowell are employed by Roane State Community College, which teaches these techniques. Seth C. Hawkins is EMS Educational Advisor for Western Piedmont Community College, Executive Director of the Appalachian Center for Wilderness Medicine, Medical Director of Burke County EMS, Course Director of the Carolina Wilderness EMS Externship, and an instructor at the Wilderness Medical Society Student Elective, all of which have taught these techniques.

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Wilderness EMS Externship, Daniel Willner, MSIV, and Justin Sempstrott, MD, disassembled EpiPens and made recommendations to the manuscript. Note that a video is available from the manufacturer demonstrating appropriate traditional administration of the post-2010 EpiPen (http://www.epipen.ca/en/about_epipen/how_to_use_epipen/).

Supplementary Videos

Supplementary videos associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.wem.2013.03.025>.

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