A systematic review of patients', parents' and healthcare professionals' adrenaline auto-injector administration techniques

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Abstract

Introduction
In order to enable fast treatment response to anaphylactic reactions, adrenaline auto-injectors (AAI) have been developed and manufactured. It has been reported in several studies that administration technique is suboptimal. The primary purpose of this study was to review the nature and extent of the deficiencies in administration technique amongst patients, parents/caregivers and healthcare professionals.

Methods
Relevant publications were identified between 1998-2015 using two search methods: a keyword search in Embase, Pubmed, BNI and CINAHL and a search of reference lists of relevant articles.

Results
Twenty three studies met the inclusion criteria. Overall 37% of patients, 32% of parents/caregivers and 21% of healthcare professionals demonstrated correct administration technique. For studies which employed a before and after-training study design, correct technique was achieved in 77% of patients, 79% of caregivers and 65% of healthcare professionals. The most consistently observed error was the failure to hold the device in place for the recommended time. For patients, factors associated with good technique were being aged over 18, trained in AAI administration by an allergist, prescribed an AAI for more than 30 months, having a history of severe anaphylaxis and membership of a support group. For parents/caregivers in addition to those mentioned, being given a training device with which to practice, improved technique.

Discussion
There was wide variation in administration techniques reported. However, studies designed using before and after-training show that even a brief demonstration and educational intervention can improve technique. Further studies are required to design and pilot acceptable and cost-effective educational materials.
What this paper adds?

- Numerous observational studies and anecdotal evidence have suggested that patients and health professionals use of adrenaline auto-injectors (AAIs) is suboptimal
- This review identifies which steps to administration are contributing to this failure and what factors are linked to success
- This review highlights the step to administration most frequently failed (holding the device in place for the recommended time)
- Additionally, this review identifies successful interventions and patient-factors (e.g. severity of allergy, age of AAI-owner) which are shown to improve administration
- The identification of these successful approaches are timely as the European Medicines Agency have released a call for better training tools recommended to support patients who use AAIs

Abbreviations

AAI: Adrenaline auto injector
EAACI: European Academy of Allergy & Clinical Immunology
HCPs: Health Care Professionals
PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analyses
MMAT: Mixed Method Appraisal Tool
EMA: European Medicines Agency
**Introduction**

Adrenaline auto-injectors (AAIs) are first line treatment for anaphylaxis in the community. Prompt injection with adrenaline can be life-saving and abort the progression of the anaphylactic reaction, allowing time to seek formal medical assessment and management. The European Academy of Allergy and Clinical Immunology (EAACI) describes six absolute indications for the prescription of an AAI including food and latex anaphylaxis, exercise-induced anaphylaxis, idiopathic anaphylaxis, moderate to severe persistent asthma with food allergy, venom allergy or underlying mast cell disorder (1). Unlike other allergic conditions, such as rhinitis and eczema, whose prevalence appears to be stabilising over the last decade, anaphylaxis appears to be increasing (2). Rates of hospital admissions in the UK for all causes of anaphylaxis increased seven-fold between 1992-2012 whilst prescriptions for AAIs increased four-fold from 1998-2012 (3). Anaphylaxis is the cause of approximately 20 deaths each year in the UK (4).

AAI is the main emergency treatment for individuals experiencing anaphylaxis, but its effectiveness is largely reliant on correct administration. Over the last few years, studies have assessed healthcare professionals’, patients’ and parents’ administration techniques and skills with respect to the emergency management of anaphylaxis. The primary purpose of this review was to assess the magnitude of the deficit in administration technique and to summarise which stages in the process of administering AAIs are most problematic. Reviewing data from a broad number of studies will help inform the development of AAI design and educational interventions for improving future utilisation.
**Methods**

**Search strategy**

A systematic review of literature published between January 1998 to August 2015 was undertaken using four databases (Embase, Pubmed, BNI and CINAHL) (see online supplementary appendix 1). Subsequently a search of the reference lists from relevant papers was performed. No language restrictions were applied.

**Inclusion and exclusion criteria**

This review focused on studies that included an assessment of AAI technique (either by demonstration or questionnaire) in three populations: patients (paediatric and adult), parents/caregivers of children diagnosed with anaphylaxis and prescribed an AAI device and health care professionals (HCPs). Studies were eligible if they were quantitative in nature including cross-sectional/observational studies, before-and-after studies or randomised controlled trials.

**Study selection**

Two reviewers (CJ and AT) independently reviewed the titles and then abstracts of articles generated by the electronic bibliographic search, rejecting any articles that clearly did not meet eligibility criteria. There was no disagreement between reviewer's regarding the eligibility of the studies although both reviewers were unsure of inclusion of three studies. These were discussed with a third author (HS) and a consensus reached. The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) (5) flow diagram was used to summarise the systematic review process (Figure 1). Authors of relevant published conference abstracts were contacted to determine if full study details were available.

**Data extraction**

The process of AAI administration is frequently described by manufacturers and researchers as six component steps (device recognition, removal of safety cap, selection of appropriate injection site, application of correct end of device to body, administration of adrenaline and retaining AAI in
place). We adopted these commonly used steps to prepare a standardised data extraction form and extracted data from the papers on participants' ability relating to each of these steps (Tables 1-3). One reviewer (AeT) extracted the data with a second (CJ) cross-checking 50% to ensure accuracy which was high. In addition we noted any additional skills or knowledge assessed, (i.e. checking expiry date of the AAI), and any factors which were associated with correct administration technique.

Assessment of study quality

All studies included in the systematic review were evaluated for quality using the mixed methods appraisal tool (MMAT) (6). The MMAT has proven to be an effective and practical quality assessment tool for systematic reviews which include different study designs or mixed methods (7). The tool consists of two screening questions followed by four criteria for the appraisal of study quality according to study design. The MMAT enabled all studies included in this review to be assessed within each of the methodological domains used. The MMAT scores range from to 0% (no criterion is met) to 100% (all four criteria are met). Studies were assessed by one reviewer experienced in conducting quality assessments (CJ). 25% of the studies were checked by a second reviewer with any disagreement being resolved by discussion until consensus was reached.

Results

From 1434 studies a total of 23 studies met the inclusion criteria (Figure 1). Eight studies came from the UK (8-15), six from North America (16-21), four from Turkey (22-25), three from Australia (26-28), and two from Israel (29,30) (Tables 1, 2 & 3). Sixteen studies were cross-sectional five were before and after studies, one was a longitudinal survey and one was a randomised controlled trial. Nineteen papers requested participants to demonstrate use of the AAI. Four studies used a questionnaire technique in which the participants responded to true/false questions or described their technique. The papers varied in their focus, four assessed the techniques and skills of patients only, eight focussed on parents/caregivers only and six papers on HCPs only. Five
studies had broader focus; four of which included patients and parents/caregivers, and one study included patients, parents/caregivers and HCPs. The findings of the studies are presented to reflect the three populations of interest; patients (9 studies), parents/caregivers (13 studies), and HCPs (7 studies), with studies reporting multiple populations presented in each of the relevant tables (Tables 1-3). The studies which employed a before and after design or RCT of the effect of instruction on AAI technique were isolated in order to clearly reflect on these findings (Table 4).

Patients

We identified nine studies (550 participants) which documented patient AAI administration technique; all were based in allergy clinic settings (Table 1). Administration assessments varied from five to nine steps. Overall, prior to receiving any instruction or demonstration as part of the study, 37% of patients were able to demonstrate or detail correct administration technique (range 6-74%). This rose to 77% overall for two studies which reported a before and after instruction design (Table 4). The most consistently reported error was the failure to hold the AAI in place for 10 seconds (step 6 Table 1), followed by a failure to apply enough pressure to activate (step 5 Table 1). Six studies reported whether patients had received previous training on how to use AAI, on average 71% patients reported either visual instruction using a trainer device or verbal instruction (range 11-100%). Five studies identified five patient-related factors associated with good AAI technique: being aged over 18, being trained by an allergy specialist, having an AAI for more than 2½ years, membership of a support group and having a history of severe anaphylaxis.

Parent/caregivers

We identified 13 studies documenting parental/caregiver AAI administration technique, ten of which reported the number of parents/caregivers participating (1182 participants). Eleven studies were based in allergy clinics, one study recruited participants from local schools and another from support groups and a private allergy clinic. Out of the 5 studies which reported findings for both patients/caregivers and patients, three did not provide separate results for parents/caregivers and patients and report patients and parents/caregivers results together. Overall, prior to receiving any
instruction or demonstration, 32% of parents/caregivers were able to demonstrate or detail correct administration technique (range 6-57%). This average rose to 79% in the five studies which reported a randomised trial or before and after instruction design in parents/caregivers (Table 4).

Amongst parents or caregivers, the most common errors were the same as those reported for patients; a failure to hold the AAI in place for 10 seconds (step 6), followed by a failure to apply enough pressure to activate (step 5) (Table 2). Nine studies reported whether parents or caregivers had received training or demonstration on how to use AAI, on average 70% said they had received some form of training (range 11-100%). Seven studies reported eight parental/caregiver related factors which were associated with proper AAI administration technique which were having a child with: more serious reactions, an AAI for more than 2½ years, membership to a support group, an AAI prescribed from secondary care, an AAI prescribed by an allergy specialist, insect sting allergy, a training device with a Auvi-Q (audio-prompt) device.

Health care professionals (HCPs)

We identified seven studies which documented HCPs AAI administration technique (923 participants); two were based in primary care, two in paediatric departments and one each in an allergy clinic, community pharmacy and a medical conference (Table 3). Overall, 21% of HCPs were able to demonstrate proper AAI technique prior to receiving any demonstration or instruction. One study reported a before and after instruction study design and showed an increase from 18% to 65% in proper AAI technique amongst community pharmacists (Table 4). The most commonly reported error was the failure to hold the AAI in place for at least 10 seconds (step 6) (Table 3). Accidental digital injection would have occurred in 21% of participants. One study reported the risk of accidental digital injection reduced from 36% to 7% post-education. Three studies reviewed how many HCPs provided training on AAI technique to their patients, which was 28% overall (range 19-51%). In the two studies which looked at factors associated with proper AAI administration technique amongst HCPs, two factors were identified: being a pharmacist and having a more general awareness of anaphylaxis management (specifically asking patients about a management
plan, advising patients to call an ambulance after administration and explaining the side effects of adrenaline).

Quality assessment

Of the 23 studies included in this systematic review, no studies scored 100%, five studies scored 75% (three criteria met), nine scored 50% (two criteria met), seven scored 25% (one criterion met) and 2 studies scored 0 (Tables 1-3, online supplementary online appendix 2). Shortcomings in study quality were often found in the description of the sampling strategy used and the failure to include a sample size calculation. It was also difficult to ascertain the response rate of studies and any differences between responders and non-responders. Patients were often inadequately described and it was not always clear who the respondents were. Although most studies adequately reported how AAI administration was assessed, this varied significantly between studies.

Discussion

Administration technique and skills in using AAI have been documented to be consistently deficient over the last 17 years across six different countries. Correct administration technique varied widely but overall was 30% for patients, 32% for parents/caregivers and 21% for HCPs. For studies which employed a before and after design of the impact of training, correct technique was achieved in 77% in patients, 79% in caregivers and 65% in HCPs. Approximately 70% of patients and parents/caregivers reported receiving some form of AAI training yet only 28% of HCPs reported providing training. The most consistently observed error common to all three populations was the failure to hold the device in place for the recommended time, and additionally for patients and parents/caregivers, the failure to apply enough pressure to activate.

In addition to observing correct administration technique, 14 studies reported factors related to proper administration technique. For patients, being aged over 18, trained in AAI use by an allergist, prescription of an AAI for more than 30 months, history of severe anaphylaxis and
membership of a support group, were all related to better technique. In addition to those already
mentioned, for parents/caregivers, having a training device with which to practice and using an
Auvi-Q instead of an EpiPen or Anapen were also correlated with better administration technique.
Pharmacists and other HCPs who had a greater general awareness of managing anaphylaxis also
demonstrated better administration technique.

This is the first systematic review to explicitly detail the deficiencies in HCPs’, patients’ and
parent/caregivers’ AAI administration technique. This review also identified seven studies which
used a study design to improve administration technique. Several educational approaches to
improving technique were reported varying from a simple two minute demonstration of
administration using a training device to a multidisciplinary approach involving an individualised
anaphylaxis management plan, followed by education from a clinical nurse specialist and a dietetic
assessment to provide families with advice on food avoidance. The time between training and
assessment varied from immediate to approximately one year indicating that some of the training
techniques were effective at improving administration over a long term period. The identification of
these successful approaches are timely as the European Medicines Agency have released a call
for better training tools recommended to support patients who use AAs (31).

There are some limitations to the conclusions drawn from this review. Results in three studies were
not separated to reflect administration techniques of the patients and parents/caregivers giving a
total score for both which could suggest why overall scores and most common errors were
mirrored between these groups. Additionally, the estimates of correct administration technique may
be optimistic for three reasons. Firstly, the majority of participants in these studies were self-
selected with often no description of differences between responders and non-responders, and
may reflect responder bias. However, we know from a recent study involving mothers of non-
allergic children with no previous experience of AAs that only 15% were able to administer the
device (32), a figure which falls in the range of correct administration scores by experienced
parents/caregivers found in this systematic review (6-57%). Secondly, although the majority of
studies used demonstration to assess administration (82%), self-reported questionnaires were used in the remaining studies indicating that findings may not reflect actual behaviour. Thirdly, it is difficult to capture how the high pressure situation of a “real-life” anaphylaxis emergency would impact AAI administration technique compared to the more controlled scenarios proposed in the research setting.

In relation to the scores used to determine correct technique in studies, these varied from zero to nine steps with some items not directly related or not critical to administration (i.e. awareness of an expiry date) which may underrepresent ability to administer device. The studies included in this systematic review related predominantly, but not exclusively, to one particular device (EpiPen). The introduction of newer AAI such as the next generation EpiPen, Jext, Emerade and Auvi-Q may impact on future assessments, although the majority of these devices use the same/similar injecting mechanisms. The most recent study in this review compared AAI use between devices and found that when prescribed a new device without receiving specific training, successful administration rates for mothers were higher with Auvi-Q (an audio-prompt AAI) (93%) than other traditional devices (i.e. EpiPen, Anapen, Jext) (49%) (15). It is likely that correct administration rates will increase if audio-prompt devices are made readily available. However, the steps identified as being most likely to be performed incorrectly (e.g. holding the device for the recommended time and applying enough pressure to activate), are common to all AAI and emphasising the importance of this to patients, parents/caregivers and HCPs during training is essential. Some may argue that the interval between triggering the device and removal of the needle need not be 10 seconds as research has found that for the EpiPen, delivery time is 0.3 seconds (33). However, there are no disadvantages to holding the device in place for a longer period as this discourages rapid removal and is consistent with the majority of manufacturer guidelines (Epi-Pen, Jext, Anapen), although the more recently introduced Auvi-Q recommends 5 seconds. Related to training, we observed a 2.5 fold increase in correct administration technique for patients and parents/caregivers and 3-fold increase in HCPs emphasizing the beneficial effect training can have on technique.
Two non-systematic short-cut reviews conducted in 2013 to determine knowledge of correct AAI use in parents of allergic children and doctors (34,35) failed to identify five key studies. Our more recent, robust and extensive systematic review involving four databases, including papers published in any language identified these five studies plus two more recently published studies. We also present evidence on the most commonly reported mistakes in administration technique, important for the design of future studies which need to move away from documenting poor technique and towards interventions to improve administration technique. Furthermore, our systematic review differentiates between patients, parents/caregivers and HCPs’ correct use of auto-injectors and identifies factors related to successful administration technique.

**Clinical implications**

The lack of correct administration technique among patients and parent/caregivers is worrying, but of greater concern is the variation in techniques observed amongst HCPs. Familiarity with epinephrine as the first-line response in the treatment of anaphylaxis was widespread but fewer were able to detail correct auto-injector technique, suggesting that if prescribing AAI, HCPs could be misinforming or not informing patients how to use the device correctly. The latter is likely given the observation that the majority (70%) of patients and parent/caregivers received training on how to use the device yet only 28% of HCPs included in this review reported providing training. It may be useful to identify those who provide training (if not the HCPs in this review), to ensure that their methods, knowledge and resources are up-to-date. Also, only five studies looked at recognition of symptoms of anaphylaxis or indications for using AAI with wide variation in those which reported results. Indications for AAI use is important to address during patient consultation to avoid either inappropriate use and consequent emergency admissions or more importantly, fatalities from the delayed administration of AAI (36).

Indicators of poor technique and ability were found amongst those patients who were instructed on the use of device or cared for by general practitioners or non-allergy specialists compared to those
cared for by allergy specialists. Those cared for by an allergy specialist were more confident and more likely to carry and have the ability to activate the device. Other significant associations were found. For instance, several studies reported significant positive effects on technique and performance if the patient was a member of an allergy support group. Further work is underway to determine which aspects of support groups are important to patients in terms of knowing how and when to use their AAI but highlights the importance of recommending patients to join support groups. There was no effect on performance in relation to the time interval since training was received. Specifically, two studies showed that correct technique was no more likely to be demonstrated if training had been received in the last six months or over 24 months. This demonstrates the necessity for thorough training in the use of the device at initial consultation.

**Future Studies**

With this plethora of studies documenting poor administration technique it is time to concentrate on identifying and designing interventions targeting these areas of poor technique highlighted. Patients and parents/caregivers should be involved in the design of training resources to ensure they are acceptable and understandable in order to address their learning needs. Amongst HCPs, training regarding the use of the device and how to communicate this effectively to patients should be addressed as well as ensuring training devices are available to supply to their patients. Successful educational materials and tools have been identified but further studies should be conducted to determine the cost-effectiveness of these approaches. Further research is required to address other important issues such, poor retention of information (by HCPs and patients/caregivers) after training, the frequency of re-training needed, and how to balance time needed to train versus HCPs' other time constraints.
Acknowledgements:

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Statement of contribution by author:

CJ, HS and CD designed the protocol for the systematic review. CJ and AE conducted separate searches to ensure all eligible studies were identified and included. Data extraction was conducted by CJ and AE before verification by HS and CD. CJ and AE drafted the initial manuscript with substantial involvement from HS and CD.

Conflict of interest:

Dr Aisha El-Turki, Professor Helen E Smith, Dr Carrie D Llewellyn and Dr Christina J Jones declare that they have no conflict of interest.


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31. European Medicines Agency. Better training tools to support patients using adrenaline


Figure 1: PRISMA flow diagram for the identification of studies assessing healthcare professionals and patients’ administration techniques of adrenaline auto-injectors

- Records identified through database searching (n=1440)
- Additional records identified through other sources (n=5)

Records after duplicates removed (n=1434)

Records screened (n=1434)

Records excluded at title/abstract (n = 1394)

Published abstract n=7

Full-text articles assessed for eligibility (n=33)

Full-text articles excluded, with reasons (n=10)
- No assessment n=7
- Systematic reviews n=2
- Administration in terms of dose & route of admin n=1

Studies included in qualitative synthesis (n=23)
- Patients only n=4
- Parents only n=8
- Patients and parents n=4
- Health care professionals only n=6
- All n=1
Table 1. Adolescent and adult patients’ technique and skills administering an adrenaline auto-injector (Studies are presented in chronological order)

<table>
<thead>
<tr>
<th>Studies (country, design, method of observation, quality assessment)</th>
<th>Study population</th>
<th>% individuals correctly undertaking key steps of AAI administration (wording used)</th>
<th>100% correct</th>
<th>Additional observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huang, 1998 USA Cross-sectional Assessment by demonstration 50%</td>
<td>98 patients (83 aged &lt;18y, 15 aged ≥18y) For &lt;12ys, parents were assessed (exact number not provided)</td>
<td>Not assessed 90% (&quot;Remove the cap&quot;) 78% (&quot;Press the Epi-PEN on the lateral thigh&quot;)</td>
<td>Not assessed 37% (&quot;Hold Epi-PEN in place for at least 10 seconds&quot;)</td>
<td>Not reported 16% knew the circumstances in which the use of AAI is indicated 84% had two devices available 53% knew to use through clothing 97% aware of expiry date but 89% had a valid device with them 11% had previously been trained in how to use AAI (5% by an allergist and 6% by other physician)</td>
</tr>
<tr>
<td>Goldberg and Confino-Cohen, 2000 Israel Cross-sectional Assessment by demonstration 75%</td>
<td>96 patients (n=72 aged &lt;12y) Children aged ≥12y were assisted in answering questions by parents and results indicate parental response (n=24)</td>
<td>Not assessed 82% (&quot;Pulling out the grey safety tip&quot;) 82% (&quot;Holding the device in palm&quot;) 82% (&quot;placing the black tip on the outer thigh&quot;) 76% (&quot;Pressing in hard until the trainer function is heard&quot;) 78% (&quot;Holding it in place for 10 seconds&quot;)</td>
<td>36% patients ≥12 y</td>
<td>89% had previously been trained in how to use AAI (46% by an allergist, 12% by a nurse, 10% by a primary physician, 10% by a pharmacist, 1% by emergency department physician and 9% by a non-professional) Mean time since last training received was 2.6 years 18% received instruction with training device Proper injection technique was more common among patients &gt;18years who were trained by an allergist</td>
</tr>
<tr>
<td>Sicherer et al., 2000 USA Cross-sectional</td>
<td>101 families of newly referred food allergic children (95 68% approx.* (&quot;Familiar with device&quot;) 55% approx.* (&quot;Removes cap&quot;) 93% approx.* (&quot;Selects correct end&quot;) 93% approx.* (&quot;Selects correct injection site&quot;) 59% approx.* (&quot;Presses to activate&quot;) 53% approx.*</td>
<td>38% Patient/Parents</td>
<td>* Approximate values extracted from graphs in published paper</td>
<td></td>
</tr>
<tr>
<td>Study</td>
<td>Assessment by demonstration</td>
<td>Parents &amp; 6 children &gt;12y &amp; 36 physicians</td>
<td>50%</td>
<td>64% (“Take the cap off”)</td>
</tr>
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<tr>
<td>Al-Matar and Sussman, 2001 Canada</td>
<td>55 patients aged 4-67y (mean age 34y) (unclear if younger aged participants were assessed directly or responses referred to parents)</td>
<td>Not assessed</td>
<td>64%</td>
<td>64%</td>
</tr>
<tr>
<td>Sabroe et al., 2002 UK</td>
<td>29 patients (13y-67y) Only 25 patients completed demonstration</td>
<td>Not assessed</td>
<td>79%</td>
<td>88%</td>
</tr>
</tbody>
</table>
### Diwakar et al., 2010

**UK**  
Cross-sectional  
Assessment by questionnaire  
25%

<table>
<thead>
<tr>
<th>Patients</th>
<th>Age</th>
<th>% Not Reported</th>
<th>% Not Reported</th>
<th>% Not Reported</th>
<th>% Not Reported</th>
<th>Other Technique Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 patients (mean age 37y (SD 15y))</td>
<td>Not assessed</td>
<td>Not assessed</td>
<td>Not assessed</td>
<td>Not assessed</td>
<td>Not reported</td>
<td>Knowing AAI can be used through clothing, what to do after injecting AAI and symptoms which would precede use (max score 7)</td>
</tr>
</tbody>
</table>

73% replaced AAI according to expiry date and of these, 53% knew the expiry date  
93% trained in how to use device (70% by hospital staff, 30% by a general practitioner and 7% by a pharmacist)

### Segal et al., 2012

**Israel**  
Before and after study with average 12 months between instruction and re-assessment  
Assessment by demonstration  
50%

| Patients | Pre-instruction | Pre-instruction | Pre-instruction | See previous step | Pre-instruction | 6% were able to complete all steps at baseline (n=141)  
≤19% were able to complete all steps at first follow up (n=41)  
≤53% were able to completed all steps at second follow up (n=41) |
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>141 (129 parents of patients aged ≤12y and 12 patients age &gt;12y (total age range 22m-23.4y))</td>
<td>Not assessed</td>
<td>Pre-instruction 52% (&quot;Removing the cap&quot;)</td>
<td>Pre-instruction 32% (&quot;Holding the device in first&quot;)</td>
<td>Pre-instruction 34% (&quot;Placing against upper outer thigh and pressing&quot;)</td>
<td>See previous step</td>
<td>Pre-instruction 26% (&quot;Holding in place for 10 seconds&quot;)</td>
</tr>
</tbody>
</table>

77% able to cite at least 2 symptoms of systemic allergic reaction  
79% had a valid device  
100% trained in how to use device  
No significant difference between patients and parents demonstration technique

### Topal et al., 2013

**Turkey**  
64 (50 caregivers of patients and 14 approx.*  
74% approx.*  
87% approx.*  
100%  
100%  
92% approx.*  
36% approx. *  
36%  
84% knew how to check the expiry date

77% able to cite at least 2 symptoms of systemic allergic reaction  
79% had a valid device  
100% trained in how to use device  
No significant difference between patients and parents demonstration technique
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>Technique Assessment</th>
<th>Patients Aged ≥12y</th>
<th>Patients Aged 13-19y</th>
<th>Technique Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-sectional Assessment by demonstration</td>
<td>50%</td>
<td>50%</td>
<td>&quot;Recognise the auto injector&quot;</td>
<td>Not assessed</td>
<td>&quot;Holding it in place for at least 10 s&quot;</td>
</tr>
<tr>
<td>Jones et al., 2015 UK</td>
<td>188 patients (age 13-19y)</td>
<td>80%</td>
<td>&quot;Remove the grey safety cap&quot;</td>
<td>99%</td>
<td>&quot;Selection of appropriate injection site&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100%</td>
<td>&quot;Selecting the outer thigh&quot;</td>
<td>Not assessed</td>
<td>&quot;Identifies needle end of device&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86%</td>
<td>&quot;Applying the black end to the thigh&quot;</td>
<td>Not assessed</td>
<td>&quot;Length of time to keep needle in muscle&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>74%</td>
<td>&quot;Pressing it until it clicks&quot;</td>
<td>86%</td>
<td>18% *if additional technique items included</td>
</tr>
</tbody>
</table>

*Approximate values derived from figure

History of severe anaphylaxis was associated with correct use of AAI administration (OR:28.3, 95% CI:2.50-321.38)

No difference between parent and child competence in administering device

98% recognised symptoms of anaphylaxis

56% knew the correct grip (thumb clear of end of the device)

68% knew to seek medical advice following administration

98% aware that the device has expiry date

93% aware of using the injection through clothing

*Low % correct reported in paper as the above additional technique items were included in the total technique score.
<table>
<thead>
<tr>
<th>Studies (country, design, method of observation, quality assessment)</th>
<th>Study population</th>
<th>% individuals correctly undertaking key steps of AAI administration (wording used)</th>
<th>100% correct</th>
<th>Additional observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Huang, 1998 USA Cross-sectional Assessment by demonstration 50%</td>
<td>98 patients (83 aged &lt;18y, 15 aged ≥18y) For &lt;12ys, parents were assessed (exact number not provided)</td>
<td>Device Recognition: Not assessed 90% (&quot;Remove the cap&quot;) Removal of safety cap: 78% (&quot;Press the Epi-PEN on the lateral thigh&quot;) Selection of appropriate injection site: Not assessed 37% (&quot;Press Epi-PEN until clicking sound is heard&quot;) Application of correct end of AAI to thigh: Not assessed Administration of adrenaline: 41% (&quot;Hold Epi-PEN in place for at least 10 seconds&quot;) Holding AAI in place: Not reported</td>
<td>16% knew the circumstances in which the use of AAI is indicated 84% had two devices available 53% knew to use through clothing 97% aware of expiry date but 89% had a valid device with them 11% had previously been trained in how to use AAI (5% by an allergist and 6% by other physician)</td>
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<tr>
<td>Gold and Sainsbury, 2000 Australia Cross-sectional Assessment by questionnaire 75%</td>
<td>68 parents of children with AAI (age 1.5-19y)</td>
<td>Device Recognition: Not reported 50% (&quot;Pulling out the grey safety tip&quot;) Removal of safety cap: &gt;80% (&quot;Could describe the site of administration and apply pressure&quot;) Selection of appropriate injection site: Not reported 82% (&quot;Placing the black end on thigh&quot;) Application of correct end of AAI to thigh: Not reported 76% (&quot;Pushing in hard until the trainer&quot;) Administration of adrenaline: 78% (&quot;Holding it in place for 10 seconds&quot;) Holding AAI in place: 50% (&quot;Holding the auto-injector in place for 10 seconds&quot;)</td>
<td>24% parents of patients 5% could not recall any steps for correct use 97% had informed school staff about their child’s anaphylaxis 71% did not use their AAI to treat anaphylaxis despite it being available and in date for 69% Greater AAI administration technique was associated with parents whose children had experienced more allergic reactions</td>
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<tr>
<td>Goldberg and Confino-Cohen, 2000 Israel Cross-sectional</td>
<td>96 patients (n=72 aged &lt;12y) Children aged ≥12y were helped to answer</td>
<td>Device Recognition: Not assessed 82% (&quot;Pulling out the grey safety tip&quot;) Removal of safety cap: 82% (&quot;Holding the device in palm&quot;) Selection of appropriate injection site: 82% (&quot;placing the black tip on the outer thigh&quot;) Application of correct end of AAI to thigh: 76% (&quot;Pushing in hard until the trainer&quot;) Administration of adrenaline: 78% (&quot;Holding it in place for 10 seconds&quot;) Holding AAI in place: 42% parents of patients &lt;12y</td>
<td>89% had previously been trained in how to use AAI (46% by an allergist, 12% by a nurse, 10% by a primary physician, 10% by a pharmacist, 1% by emergency</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Design</td>
<td>Assessment by Demonstration</td>
<td>Percent</td>
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<tr>
<td>Sicherer et al., 2000 USA</td>
<td>Cross-sectional</td>
<td>101 families of newly referred food allergic children (95 parents and 6 children, mean age 6.4y) &amp; 36 physicians</td>
<td>68% approx.*</td>
<td>55% approx.*</td>
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<tr>
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<td></td>
<td>(&quot;Familiar with device&quot;)</td>
<td>(&quot;Removes cap&quot;)</td>
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<td></td>
<td>65%</td>
<td>65%</td>
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<td></td>
<td>Not reported</td>
<td>Not reported</td>
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<td></td>
<td>64%</td>
<td>64%</td>
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<td></td>
<td></td>
<td></td>
<td>Not assessed</td>
<td>Not assessed</td>
</tr>
<tr>
<td>Kapoor et al., 2004 UK</td>
<td>Cross-sectional</td>
<td>62 parents of children with AAI (&lt;17 y)</td>
<td>Not assessed</td>
<td>% not reported</td>
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<td></td>
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<td>61%</td>
<td>61%</td>
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Notes:
- Approximate values extracted from graphs in published paper
- The data presented in this publication combined findings for patients and parents. No separate results provided for patients; results combined for patients and parents
- 55% patients had non-expired AAI with them
- 49% reported previous demonstration of the device by a physician and 80% stated that use was explained verbally
- 98% said they would seek medical advice after administration
- Correct use was associated with having had the device >2.5 years and membership of a support group
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Study Design</th>
<th>Education Method</th>
<th>Initial Assessment</th>
<th>Initial Percentage</th>
<th>Critical Steps</th>
<th>Final Assessment</th>
<th>Final Percentage</th>
<th>Additional Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before-after Assessment by demonstration</td>
<td></td>
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<td>75%</td>
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<tr>
<td>Kim et al., 2005 USA</td>
<td></td>
<td>Cross sectional</td>
<td>Questionnaire</td>
<td>75%</td>
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<tr>
<td>Arkwright and Farragher, 2006 UK</td>
<td></td>
<td>Cross-sectional</td>
<td>Demonstration</td>
<td>50%</td>
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<tr>
<td>Huang, 2007 UK</td>
<td></td>
<td>Longitudinal survey after auto-injector demonstration (assessment at 3 month intervals)</td>
<td>Demonstration</td>
<td>50%</td>
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</table>

**Steps Assessed:**
- "Removal of the grey safety cap"
- "Selecting the appropriate site"
- "Pressing the EpiPen down until it click"
- "Hold for 10 seconds after injection"
- "Did not take the needle out of the skin immediately after the device had been triggered"
- "Applied enough pressure to trigger the device"
- "Correct site to inject adrenaline"
- "Press until clicking sound heard"
- "Remove grey cap before administration"
- "Choose the injection site"
- "Press the device steadily for 10 seconds (count to 10)"

**Critical Steps:** Steps 2, 3, and 5

**Post-education:**
- 96% parents able to identify all three critical steps
- Participants referred from secondary care had better technique than those from primary care (38% vs 15% correct AAI technique at baseline)

**Other Findings:**
- 93% knew not to remove clothing before injecting
- 77% knew to call 911 and 65% knew to go to the emergency department following administration
- 88% knew to replace if the liquid appeared brown
- 83% trained in how to use device (47% trained by a physician, 36% by a nurse)

**Additional Information:**
- 22% of parents passed all recorded steps at first visit, 68% at the 2nd visit and 94% at the 3rd visit
- At 2nd visit parental pass rate was higher for those whose child had venom allergy compared with food allergy
- 99 parents receiving a trainer device had a better pass rate at 2nd visit
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Study Design</th>
<th>Population Description</th>
<th>Participants</th>
<th>Assessment</th>
<th>Pre-instruction</th>
<th>Immediate post-education</th>
<th>Longitudinal with before and after follow-up</th>
<th>No Significant Difference Between Patients and Parents Demonstration Technique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Segal et al., 2012</td>
<td>Israel</td>
<td>Longitudinal</td>
<td>141 mothers of children with AAI aged ≤12y and 12 aged &gt;12y (total age range 22m-23.4y)</td>
<td>129 parents</td>
<td>Pre-instruction</td>
<td>52% (&quot;Removing the cap&quot;)</td>
<td>32% (&quot;Holding the device in first&quot;)</td>
<td>34% (&quot;Placing against upper outer thigh and pressing&quot;)</td>
<td>26% (&quot;Holding in place for 10 seconds&quot;)</td>
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<tr>
<td>Sicherer et al., 2012</td>
<td>USA</td>
<td>Longitudinal</td>
<td>60 families (parent/caregiver of a food allergic child prescribed AAI aged 6 months to 14y)</td>
<td>60 families</td>
<td>Pre-instruction</td>
<td>38% approx.* (&quot;Recognises device&quot;)</td>
<td>78% approx.* (Immediate post-education 100%)</td>
<td>12-months post-education 70% (&quot;Removes cap&quot;)</td>
<td>12-months post-education 96% (&quot;Correct site&quot;)</td>
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<tr>
<td>Topal et al., 2012</td>
<td>Turkey</td>
<td>Cross-sectional</td>
<td>64 (50 care givers of children with AAI and 14 patients aged ≤12y)</td>
<td>64</td>
<td>Pre-instruction</td>
<td>72% approx.* (&quot;Recognise the autoinjector&quot;)</td>
<td>70% approx.* (Immediate post-education 100%)</td>
<td>12-months post-education 70% (&quot;Removes cap&quot;)</td>
<td>12-months post-education 96% (&quot;Correct end&quot;)</td>
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<tr>
<td>Umasunthar et al., 2015</td>
<td>UK</td>
<td>Cross-sectional</td>
<td>158 mothers of children (aged 0-18y) with food allergy (145 completed 6-week assessment, 110 completed)</td>
<td>158</td>
<td>Not assessed</td>
<td>6-weeks post-training Anapen 63%, EpiPen 71% 12-months post-training Anapen 66%, EpiPen 90% 6-weeks post-training Anapen 93%, EpiPen 93% 12-months post-training Anapen</td>
<td>6-weeks post-training Anapen 100%, EpiPen 82% 12-months post-training Anapen 88%, EpiPen 88%</td>
<td>6-weeks post-training Anapen 86%, EpiPen 82% 12-months post-training Anapen 88%, EpiPen 88%</td>
<td>6-weeks post-training Anapen 42%, EpiPen 43% 12-months post-training Anapen 55%, EpiPen 59%</td>
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</tbody>
</table>
RCT to receive EpiPen or Anapen and training
Assessment by demonstration 6 weeks and 1 year after initial training
50%

| 12-month assessment | 100%, EpiPen 83% | 100%, EpiPen 98% | At 12-months, 0% with Anapen and 14% EpiPen injected into the thumb, 80% Anapen and 63% EpiPen massaged site after injection, 86% Anapen and 93% EpiPen called the emergency services
After 12-months, 108 participants were given an alternate device with no training. Participants receiving the Auvi-Q had highest administration success rate 93% vs 49% for all other devices |
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<tbody>
<tr>
<td>(&quot;Removal of all safety caps&quot;)</td>
<td>(&quot;Placement of correct end of the device against the thigh&quot;)</td>
<td>(&quot;Activation of device&quot;)</td>
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<td>100%, EpiPen 98%</td>
<td>(&quot;Holding the device in place for adrenaline delivery for ≥5s&quot;)</td>
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</table>
Table 3. Health care professionals’ (HCPs) technique and skills administering an adrenaline auto-injector (Studies are presented in chronological order)

<table>
<thead>
<tr>
<th>Studies (country, design, method of observation, quality assessment)</th>
<th>Study population</th>
<th>% individuals correctly undertaking key steps of AAI administration (wording used)</th>
<th>100% correct</th>
<th>Additional observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grouhi et al., 1999 Canada</td>
<td>122 HCPs (physicians, medical students, pharmacist and nurses) Secondary care</td>
<td>Device Recognition: Not assessed</td>
<td>Removal of safety cap: 56% approx.* (&quot;Pull out the grey safety cap&quot;)</td>
<td>Selection of appropriate injection site: 44% approx.* (&quot;Hold the device in the palm with the thumb covering the index finger and the black tip toward the small finger&quot;)</td>
</tr>
<tr>
<td>Sicherer et al., 2000 USA</td>
<td>101 families of newly referred food allergic children (95 parents and 6 children, mean age 6.4y) &amp; 36 physicians Secondary care</td>
<td>Device Recognition: Not reported</td>
<td>Removal of safety cap: 35% paediatricians 51% paediatric residents approx.* (&quot;Familiar with device&quot;)</td>
<td>Selection of appropriate injection site: 83% paediatricians 90% paediatric residents approx.* (&quot;Removes cap&quot;)</td>
</tr>
<tr>
<td>Onbasi et al., 2005 Turkey</td>
<td>93 physicians Primary care</td>
<td>Device Recognition: Not reported</td>
<td>Removal of safety cap: Not reported</td>
<td>Selection of appropriate injection site: Not reported</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Setting</td>
<td>Setting Type</td>
<td>Method of Assessment</td>
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<tr>
<td>Mehr et al., 2007</td>
<td>Australia</td>
<td>Tertiary care</td>
<td>Cross-sectional</td>
<td>Demonstration by demonstration</td>
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<td>Arga et al., 2011</td>
<td>Turkey</td>
<td>Secondary care</td>
<td>Before-after study</td>
<td>Demonstration by demonstration</td>
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<td>Salter et al., 2014</td>
<td>Australia</td>
<td>Community care</td>
<td>Cross-sectional</td>
<td>Simulated patient-study</td>
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<td>Topal et al., 2014</td>
<td>Turkey</td>
<td>Primary care</td>
<td>Cross-sectional</td>
<td>Demonstration by demonstration</td>
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<tr>
<td>Studies</td>
<td>Type of instruction</td>
<td>Method of observation</td>
<td>Duration of retest</td>
<td>Correct administration technique</td>
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<tr>
<td>Al-Matar and Sussman, 2001</td>
<td>Two minute instruction of correct administration technique was provided</td>
<td>Demonstration using a trainer device</td>
<td>Immediately following instruction</td>
<td>Pre-instruction 13%</td>
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<td>Post-instruction 100%</td>
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<tr>
<td>Kapoor et al., 2004</td>
<td>A clinical nurse specialist educated participants on recognition and management of anaphylaxis. A specialist paediatric dietician gave advice regarding food allergen avoidance.</td>
<td>Demonstration using a trainer device</td>
<td>3 months</td>
<td>Pre-instruction 50%</td>
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<td>Post-instruction 96%</td>
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<tr>
<td>Huang, 2007</td>
<td>A physician observed participants demonstration technique before explaining any steps which needed to be corrected prior to demonstrating correct technique. Participants were then required to repeat the process until they completed all steps correctly.</td>
<td>Observation by physician</td>
<td>No reported (first, second and third visits but duration between not provided)</td>
<td>Pre-instruction (first visit) 22%</td>
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<td>Post-instruction (second visit) 68%</td>
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<td>Post-instruction (third visit) 94%</td>
</tr>
<tr>
<td>Arga et al., 2011</td>
<td>One-to-one practical session including visual and written prospectus on how to use AAI</td>
<td>Demonstration using a trainer device</td>
<td>6 months</td>
<td>Pre-instruction 23%</td>
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<td>Post-instruction 74%</td>
</tr>
<tr>
<td>Segal et al., 2012</td>
<td>Participants received an individualized written emergency plan and instructions for the use of AAI plus training from one of three physicians</td>
<td>Demonstration using a trainer device</td>
<td>First follow-up visit after 0.04–6.54 years (mean 1.28 years)</td>
<td>Pre-instructions 6%</td>
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<td>First follow up ≤19%</td>
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<td>Second follow up ≤53%</td>
</tr>
<tr>
<td>Sicherer et al., 2012</td>
<td>Education materials (written and video) on signs and symptoms of food allergy, labelling and when and how to use AAI</td>
<td>Demonstration using a trainer device</td>
<td>Immediate post-instruction and 12 months</td>
<td>Pre-instruction 18%</td>
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<td>Immediate post-instruction 95%</td>
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<td></td>
<td>12-months post-instruction not reported</td>
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<tr>
<td>Umasonthar et al., 2015</td>
<td>Standardised training including recognition and management of anaphylaxis by researcher who ensured participants were able to demonstrate correct technique before leaving the session plus written manufacturer device specific information</td>
<td>Demonstration using a trainer device</td>
<td>6 weeks and 12 months</td>
<td>6-weeks post-instruction Anapen 42%, EpiPen 43%</td>
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<td>12-months post-instruction Anapen 55%, EpiPen 59%</td>
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