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Administration of adrenaline by trainee teachers in a simulated anaphylactic reaction: intramuscular versus intranasal use

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Abstract
Introduction: Anaphylactic reactions represent a serious risk for children within the school environment. It is essential that teachers are prepared to respond quickly and effectively. The objective of this study was to evaluate the ability of trainee teachers to administer adrenaline, both intramuscularly and intranasally, in a simulated anaphylactic shock scenario.
Material and methods: This quasi-experimental pilot study included 23 undergraduate students in Primary Education who received training in managing severe allergic reactions. They were evaluated twice in a simulated anaphylaxis scenario. In the first test, participants chose the adrenaline device (intramuscular or intranasal). In the second, they repeated the scenario using the alternative device. Variables related to the execution of each step and the time required were recorded.
Results: More than 80% of participants correctly completed all steps with the intranasal device. However, greater difficulties appeared with the intramuscular autoinjector, particularly maintaining it in position for at least 5 seconds and massaging the area afterward, which only 20% completed. The correct compliance rate was significantly higher with the intranasal

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device (100% vs. 71.43%, p = 0.012), and the administration time was shorter (p = 0.022). Initially, almost 70% chose the intramuscular autoinjector, but after testing both devices, 60.9% preferred the intranasal route.
Conclusions: A brief theoretical-practical training session is effective in training future teachers to respond appropriately to anaphylaxis in schools. Participants preferred the intranasal route for its simplicity and lower invasiveness.

Introduction

Allergies are prevalent disorders in childhood, and anaphylactic reactions can be triggered at any time and in any location, including the school environment, with food allergies representing a particular risk in dining halls or canteens. The response to an anaphylactic reaction involves not only the affected student but also classmates and teachers. Teaching staff are often concerned about the possibility of acute events among students in their care and, although they may recognize that they should be the first to act, they often report a lack of knowledge and training that raises doubts about their ability to administer necessary treatments and provide proper first aid, in addition to fearing possible legal consequences.[1-3.]

Although early recognition of an anaphylactic reaction and the availability of adrenaline auto-injectors are essential for first aid, it has been observed that many schoolchildren do not take their injectors to school, and only a small percentage of those who had them and experienced an anaphylactic shock were treated by their teachers.[3]

Recently, a new device has been introduced to the market that allows the quick, easy, and safe intranasal administration of adrenaline.[4]

The intranasal route has been used in emergency situations for several years. It allows rapid administration without the need for venous access, as mucosal absorption has proven to be effective. Examples of this route include the use of fentanyl as an analgesic, midazolam for the treatment of convulsive seizures, and naloxone for the treatment of opioid intoxication, among others. With respect to intranasal adrenaline, it has demonstrated absorption comparable to that of intramuscular administration. Moreover, its stability over long periods under varying temperature and relative humidity conditions ensures an adequate shelf life for the medication.[5]

Regarding the bioavailability of intranasal adrenaline, Lapidot et al.[6] reported that 91% of subjects receiving intranasal dry-powder adrenaline reached plasma thresholds of 100 pg/mL at 6 minutes, compared with 55% of subjects who received intramuscular adrenaline. Casale et al.¤ showed that intranasal adrenaline (Eurneffy®) has a pharmacokinetic profile within the range of currently approved adrenaline injection products. A single intranasal dose resulted in a mean Cmax of 481 pg/mL, which falls between the commercial intramuscular device EpiPen® (753 pg/mL) and manual intramuscular adrenaline (339 pg/mL). Similarly, the median Tmax for intranasal adrenaline was 30.0 minutes, intermediate between EpiPen® (7.5 minutes) and manual intramuscular injection (45 minutes). The pharmacodynamic profile was comparable to that of the commercial intramuscular device EpiPen® and similar or superior to that of manual intramuscular adrenaline injections.

Intranasal administration of adrenaline could represent a significant advance in the management of anaphylactic reactions, particularly when the intervention is carried out by non-health professionals, such as teachers. In addition, this device could make it easier for students themselves, family members, or even classmates to administer the treatment. However, there are still no data on how well this approach would be accepted by teachers or on their ability to administer adrenaline in this way.

The present study was carried out based on two hypotheses: students of the Primary Education Degree (trainee teachers) are able to use both the adrenaline autoinjector and the intranasal device in a simulated anaphylactic reaction scenario, and trainee teachers are more likely to prefer the intranasal device due to its ease of use and less invasive nature.

Materials and Methods

Study design and participants

A quasi-experimental pilot study with an exploratory scope was conducted using a convenience sample of university students enrolled in the Primary Education Teacher Degree program. The study protocol adhered to the ethical principles of the Declaration of Helsinki and was approved by the USC Bioethics Committee (registration code USC59/2022). Participation was voluntary, and all subjects were informed both verbally and in writing about the objectives of the study, as well as the research protocol and methodology, providing their written informed consent before participation.

Procedure

Participants were given an initial questionnaire assessing their general knowledge of anaphylaxis—including its causes, consequences, symptoms, and therapeutic approach—which they were required to complete within 20 minutes. The questionnaire included the following questions: “Have you ever had an anaphylactic reaction?”, “Have you ever witnessed an anaphylactic reaction?”, “What is an anaphylactic reaction?”, “Could you list causes that might trigger an anaphylactic reaction?”,

"Do you know the treatment for an anaphylactic reaction?", and "Would you know how to respond to an anaphylactic reaction?"

Then, a paediatrician from the research team (GGS) conducted a one-hour theoretical and practical training session focused on first aid response to an anaphylactic reaction. The practical component included a demonstration of adrenaline administration using both a Jext® training autoinjector and a simulator of the new Eurneffy® intranasal delivery device. Participants were encouraged to ask questions or express any doubts during the session and were provided with an email address for further inquiries or additional information if needed.

A week later, the trainee teachers were individually evaluated in a simulated scenario involving a severe anaphylactic reaction, using a checklist (Table 1) based on the European Resuscitation Council's action guidelines,[7] which included the option of administering intranasal adrenaline.

The proposed clinical scenario was as follows: "*You are supervising the children during their school break, and someone alerts you to the fact that one child, known to be allergic to nuts, is suffering from shortness of breath, a swollen tongue and throat, and feeling hot after trying another classmate's snack*".

Each participant was evaluated twice consecutively using the same scenario. In the first evaluation, they had to choose between the intramuscular device and the intranasal adrenaline atomizer as the treatment to manage the emergency. In the second, they were asked to complete the task using the device they had not selected during the first simulation. After using both devices, participants were asked which one they would choose in a real situation and to explain the reason for their choice.

The materials used for the simulation included a basic paediatric mannequin (*RCP Resusci Junior QCPR model, Laerdal*); intramuscular injection training pads to prevent surface damage to the mannequin (*Medarchitect model*); self-injectable adrenaline training devices (*Jext® 300 micrograms, ALK-Abelló*); and an intranasal glucagon training atomizer simulator (*Lilly Baqsimi®*) with the drug label removed (Table 1).

Table 1 Checklist for the simulated anaphylaxis scenario according to the selected adrenaline administration device (intramuscular or intranasal).

Intramuscular autoinjector
1. Call emergency services
2. Remove the safety cap from the autoinjector
3. Hold the autoinjector with a closed fist
4. Firmly press the autoinjector against the appropriate site on the thigh
5. Maintain the autoinjector in position for at least 5 seconds
6. Massage the injection site for a few seconds
7. Monitor the patient and administers a second dose if there is no improvement
Intranasal Atomizer
1. Call emergency services
2. Insert the nozzle into one nostril
3. Press the plunger with the thumb
4. Administer the full dose of medication
5. Monitor the patient and administers a second dose if there is no improvement

Variables

We considered each of the recommended first aid steps for an anaphylactic reaction (Table 1), the time (in seconds) required to manage the scenario, and the device preferred by each participant, along with the reasons for their choice. The correct compliance rate for each device was calculated using the following formula: (Σ steps correctly executed × 100) / total number of steps.

Statistical analysis

Sample normality was assessed using the Shapiro-Wilk test. Quantitative variables are presented as the median (Me) and interquartile range (IQR), while qualitative variables are expressed as absolute and relative frequencies. To determine the relationship between variables, non-parametric inferential statistical tests were applied. The Wilcoxon signed-rank test was used to compare quantitative variables related to the correct compliance rate and total time spent when using the intranasal device versus the injectable device. In all analyses, a significance level of $p < 0.05$ was considered. Statistical analyses were performed using SPSS software, version 25.0 for Mac.

Results

A total of 23 trainee teachers participated in the study (78% women; average age = 19 [18.0–19.0] years). Two participants (8.7%) reported having both suffered from and witnessed anaphylaxis. Nineteen (86.0%) correctly identified an anaphylactic reaction, although only seven (30.4%) considered themselves capable of intervening if they witnessed one. Sixteen (69.6%) knew the symptoms of anaphylaxis, and fourteen (60.9%) knew its causes, although only three (13.3%) were aware of the appropriate treatment.

The results of the simulated anaphylaxis evaluation are presented in Table 2. More than 80% of participants correctly performed all the required steps using the intranasal device, with the most frequent error being incomplete administration of the medication (an error made by six participants, 19%). In contrast, participants experienced greater difficulty completing the necessary steps for correct adrenaline administration with the injectable device, such as keeping the autoinjector in place for at least 5 seconds and massaging the area afterward to promote drug absorption. These steps were correctly completed by only 20% of the trainee teachers.

Table 2 presents the data on the correct compliance rate for drug administration and the administration time for both the intranasal and injectable devices. The median

Table 2 Results of the simulated anaphylaxis scenario evaluation (n = 23).

Intramuscular autoinjector	[n (%)]
Call emergency services	13 (59,10)
At the beginning	8 (36,40)
At the end	5 (22,70)
Remove safety cap from autoinjector	22 (95,70)
Aim autoinjector correctly at the thigh	22 (95,70)
Hold autoinjector with a closed fist	22 (95,70)
Firmly press autoinjector against the thigh	23 (100)
Inject adrenaline into the outer thigh	14 (60,90)
Hold autoinjector in place for at least 5 seconds	6 (26,10)
Massage the injection site for a few seconds	5 (22,70)
Action taken after case resolution	
Would take no action	1 (4,30)
Would call emergency services	5 (21,70)
Would administer a second dose	15 (65,20)
Would wait for emergency services	2 (8,70)
Total time (sec)	95,85 (65,58-113,28)
Correct compliance rate (%)	71,43 (57,14-71,43)
Intranasal Atomizer	
Call emergency services	13 (59,10)
At the beginning	6 (27,30)
At ehe end	7 (31,80)
Inserts the nozzle into one nostril	20 (95,20)
Press the plunger with the thumb	19 (90,50)
Administer the full dose of medication	17 (81,00)
Action taken after case resolution	
Would take no action	3 (13,60)
Would call emergency services	4 (18,20)
Would administer a second dose	12 (54,50)
Would wait for emergency services	3 (13,60)
Total time$_{(sec)}$	72,31 (59,57-98,22)
Correct compliance rate (%)	100 (100-100)

Qualitative variables are expressed as absolute frequencies (relative frequencies), indicating the number (n) and percentage (%) of participants who correctly performed each specific step. Quantitative variables are presented as the median (interquartile range).

correct compliance rate for the intranasal adrenaline device was 100%, whereas for the injectable device it was 71.43% (p = 0.012). The total time required for administration with the intranasal device was significantly shorter than that with the intramuscular autoinjector (p = 0.022).

Regarding the participants who performed the administration correctly and without errors, 3 (13.0%) did so using the injectable device and 17 (73.9%) using the intranasal device, with no statistically significant difference between the two.

At baseline, in the first scenario, seven participants (30.4%) chose the intranasal device, citing its ease of use, while sixteen (69.6%) opted for the intramuscular autoinjector, emphasizing its reliability. However, after testing both devices, seven of the sixteen participants who initially chose the autoinjector changed their preference in favor of the intranasal device, reassessing its ease of use, speed, and reliability. During the final assessment, fourteen participants (60.9%) selected the intranasal device, whereas nine (39.1%) maintained their preference for the injectable format.

Discussion

Taking into account the severity of anaphylaxis and the need for immediate action at the site of the emergency, first aid procedures for an anaphylactic reaction in a

school-aged child should be known both by the child themself—who should carry at least one adrenaline autoinjector—and by the responsible adults. During school hours, these adults are the teachers. Our study showed that trainee teachers initially had limited knowledge about anaphylaxis and its treatment; however, after a brief theoretical and practical training session, they were able to manage a simulated anaphylactic reaction in a hypothetical student.

Before the training, only seven participants (30.4%) believed they knew how to intervene in an anaphylactic reaction, and only two (8.7%) reported having received any prior training on anaphylaxis. These findings are consistent with those of Rodríguez-Ferrán et al.,[8] who, in a study of 53 teachers, observed that 83% were able to recognize the symptoms of an allergic reaction, although only 15% knew when and how to administer adrenaline. Therefore, if it is accepted that children experiencing an anaphylactic crisis should receive rapid and effective first aid at the site of the event—and given that such events may occur in school—it becomes necessary for teachers to receive training in this and other emergency procedures as part of their undergraduate programs.[9,10]

With regard to the mode of adrenaline administration, various intramuscular autoinjectors have been available for years and are used by family members and schoolchildren themselves after receiving training from their paediatricians, nurses, or allergists. However, it has been observed that some of these individuals, as well as untrained caregivers such as teachers, feel anxious about the possibility of not using the autoinjector correctly or even causing harm to the child.[1] Fear of injuring oneself or others can act as a barrier to both self-administration and the use of an adrenaline autoinjector by a layperson. For these reasons, new methods for self- or assisted administration of adrenaline have been developed, particularly intranasal formulations. These devices, which are already available on the market, could help increase the rate of early adrenaline administration in cases of anaphylaxis due to their less invasive nature and lower potential risk. However, awareness of these products remains limited, and no data are currently available regarding their actual ease of use or their acceptance among educators.

Our study provides new data in this regard and shows that a group of trainee teachers, when faced with a hypothetical but realistic scenario of anaphylactic shock in one of their students, preferred to use the intranasal device, administering it correctly in all cases and in a shorter time than the intramuscular option. Although these results are preliminary and were obtained in a controlled, stress-free simulation, they support the inclusion of training on intranasal device use for teachers in both Primary and Secondary Education, as well as the implementation of follow-up studies on real anaphylactic reactions in school settings. Such studies could document the actions taken by witnesses and the clinical outcomes, thereby helping to evaluate the real impact of this type of training.

It should be noted that, despite their simplicity, the use of intranasal devices still requires proper training to prevent errors such as incomplete dose delivery caused by a partial depression of the plunger, as highlighted by Settles et al.[11] With regard to the intramuscular device, the most frequently reported errors include injections administered in an inappropriate area of the body and incomplete dose delivery,[11] both of which were observed in 40% of our participants.

In this regard, participants in our study performed the technique more accurately with the intranasal device, with approximately 73% completing the procedure without errors compared to 13% with the autoinjector. This finding likely explains why most participants expressed a preference for the intranasal route after using both devices. However, it should be noted that the autoinjector requires a greater number of steps, which may complicate the procedure and increase the likelihood of errors.

Regardless of the device used, in the event of an anaphylactic reaction, the immediate notification of Emergency Medical Services (EMS) is essential, as this serves a dual purpose: providing guidance and remote support while first aid is administered by witnesses, and simultaneously activating and dispatching the appropriate resources (such as an equipped ambulance or other assistance, depending on the situation) to assume medical care on-site and transfer the patient to the nearest hospital. This point should be strongly emphasized during training activities for the general population, as studies like ours show that in many cases (approximately 40% in our study), participants did not contact EMS. In a real situation, this omission could lead to delays in definitive care and a poorer prognosis for the patient.[12,13]

The results of our study should be interpreted in light of certain limitations, including the small sample size, the participants' recruitment from a single institution, their limited prior knowledge of anaphylaxis and its treatment, and their lack of experience with adrenaline self-administration devices. The study's methodology, which relied on simulated clinical scenarios, does not permit direct extrapolation of the findings to real-life situations. In an actual anaphylactic event, the unexpected onset of symptoms and the fear of causing harm to the victim often generate stress and a certain degree of chaos—factors likely to negatively influence clinical outcomes. Furthermore, the intranasal atomizer used in the study was a non-commercial training simulator which, although replicating the design of commercial devices, may differ slightly in its physical properties, potentially affecting drug deposition.

Conclusion

A brief theoretical-practical training session proved feasible and was associated with a high rate of correct management among students of the Primary Education Teaching Degree in a simulated school anaphylaxis scenario. Trainee teachers were able to administer a dose of adrenaline to the simulated patient using either an intramuscular or intranasal device; however, they performed the procedure more accurately with the intranasal device and expressed a preference for this route due to its simplicity, speed, and less invasive nature. These findings support the inclusion of an anaphylaxis training programme within Education Sciences curricula, aiming to ensure that teachers are prepared and hold positive attitudes toward acting as the first effective responders in cases of anaphylactic reaction

at school. The intranasal route of adrenaline administration may offer advantages over intramuscular devices when used by laypersons and should therefore be further evaluated in future studies, both under simulated conditions and in real-life clinical settings.

Author's Contribution

Conceptualization: CAG, GGS, ARN; Methodology: CAG, GGS; Validation: all authors; Formal analysis: ACF; Investigation: PCV, CAG, GGS, ACF; Resources: CGM, GGS, ARN; Data curation: ACF, CAG; Writing – original draft: ACF, PCV; Visualization: ACF, PCV, CGM; Writing – review & editing: all authors; Supervision: CAG, ARN.

Conflict of Interest

The authors declare no conflicts of interest.

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