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## Training and education

# Different perceptions of thorax anatomy and hand placement for chest compressions among healthcare professionals and laypersons: Implications for cardiopulmonary resuscitation

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## Abstract

**Aim:** The European Resuscitation Council guidelines recommend that the hand position for chest compressions is obtained by “placing the heel of your hand in the centre of the chest”. Importantly, guidelines are based on a study on healthcare professionals being extrapolated to laypersons. This study explored whether healthcare professionals and laypersons differ in anatomical knowledge necessary for obtaining the correct hand position for chest compressions and understanding of European Resuscitation Council guideline recommendations in the absence of a demonstration.

**Methods:** We asked laypersons and healthcare professionals to identify where to place the hands for chest compressions on digital pictures of the chest of a man and a woman. Both groups were asked to identify where to place the hands for chest compressions, the left nipple (positive control), the centre of the chest and to delineate the anterior area of the chest.

**Results:** In total, 50 laypersons and 50 healthcare professionals were included. Healthcare professionals were significantly better at identifying the correct hand position for chest compressions compared to laypersons (male chest:  $P = 0.03$ , female chest:  $P < 0.0001$ ) and delineating the anterior area of the chest. We found no significant difference between groups when instructed to identify the left nipple nor the centre of the chest (male chest:  $P = 0.57$ , female chest:  $P = 0.50$ ).

**Conclusion:** Laypersons and healthcare professionals have different perceptions of chest anatomy and where to perform chest compressions suggesting that caution should be taken when extrapolating results from healthcare professionals to laypersons. The ERC 2015 guideline recommendations on hand placement for chest compressions seems understandable by both laypersons and healthcare professionals.

**Keywords:** Basic life support, Cardiopulmonary resuscitation, Hand position, Cardiac massage, Chest compressions, Education, Guidelines

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## Introduction

Basic life support (BLS) provided by bystanders improve survival following out-of-hospital cardiac arrest (OHCA).<sup>1,2</sup> Correct hand placement is essential to ensure an optimal physiologic response to chest compressions.<sup>3</sup> However, instructions on where to place the hands need to be easy to understand for laypersons responding to an OHCA. Accordingly, the basic life support algorithm has been simplified in order to ensure that bystanders understand the recommendations and successfully perform bystander CPR thereby increasing chances of survival.<sup>4</sup>

The 2015 ERC guidelines recommend that the hand position for chest compressions is taught by “placing the heel of your hand in the centre of the chest”.<sup>4</sup> This instruction should be accompanied by a demonstration of placing the hands on the lower half of the sternum.<sup>4</sup> This recommendation was originally formulated based on a single study, which only included healthcare professionals.<sup>5</sup> The ERC recommendation has been included in written material concerning CPR techniques developed for laypersons, including manuals, pamphlets and phone apps.<sup>6</sup> Often, no visual demonstration is given in this material.

The majority of studies providing evidence for resuscitation guidelines include healthcare professionals such as emergency medical technicians, medical students, nurses, and physicians.<sup>5,7–9</sup> The results of these studies are extrapolated to laypersons, irrespective of differences in experience, knowledge, and training. However, whether findings from healthcare professionals can be extrapolated to the lay public remains to be investigated.

We aimed to investigate if healthcare professionals and laypersons differ in anatomical knowledge necessary for obtaining the correct hand position for chest compressions and understanding of European Resuscitation Council guideline recommendations in the absence of a demonstration.

## Methods

### Subjects

Volunteering laypersons and healthcare professionals above the age of 18 were recruited. Laypersons were recruited from different companies and institutions e.g. retail shops and the city hall (Holstebro city, Denmark, 35.000 inhabitants). Laypersons were excluded if they had completed CPR training within the last 3 years, completed a healthcare education, or if they had previous employment as a healthcare provider. Healthcare professionals (i.e., subject to education in anatomy as part their basic training) were included from three different hospitals in Denmark. Data on age, sex, employment, educational level, previous CPR training, previous employment as a healthcare provider and previous performance of CPR were obtained using a questionnaire. All participants were asked if they felt capable of performing CPR.

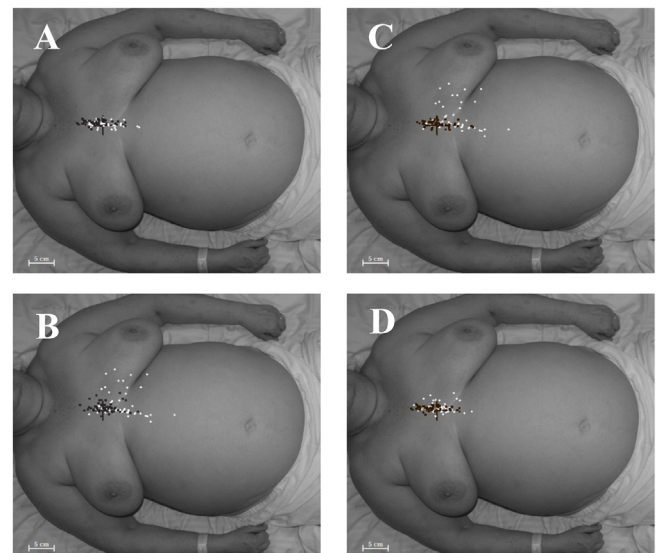
According to Danish law, no approval from an ethical review committee was required for this non-interventional study. Written consent was obtained from all participants, and the study conforms with the Declaration of Helsinki.

### Design

To study perceptions of human anatomy, two digital pictures of the chest of a male (80 years old, 172 cm, 79 kg) and a female (51

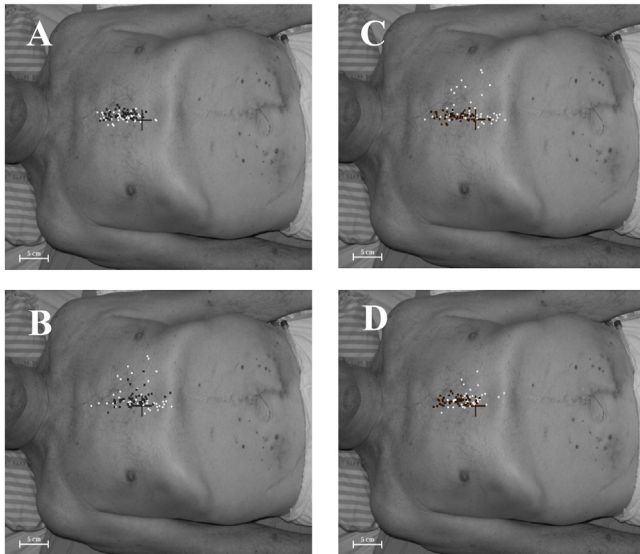
years old, 170 cm, 105 kg) patient admitted to a coronary care unit (Figs. 1 and 2) were used. We chose pictures to illustrate real-life anatomy of a patient likely to suffer from a cardiac arrest in contrast to a standard textbook anatomy picture or the chest of a resuscitation manikin, which often depict a slim, younger male. Written consent was obtained from the patients shown on the digital pictures used in the study (Figs. 1 and 2). To ensure anonymity, the face of the patients was not included in the figures.

The pictures were shown on a laptop, and anatomical points of interest were pointed out using a standard computer mouse. The sequence of pictures (male or female first) was randomized for each participant and presented on a computer screen. On each picture, participants were asked to identify three anatomical positions in the following order: 1) identify where you would perform chest compressions; 2) identify the patient’s left nipple, and 3) identify the centre of the patient’s chest. Participants were asked to point out where they would perform chest compressions to identify any possible differences in perception from the recommended position denoted as in the centre for the chest (anatomically equal to the lower half of the sternum) without the bias of a preexisting suggestion. Identification of the left nipple was used to ensure correct anatomical understanding and use of the software (positive control). Finally, participants were asked to delineate the anterior area of the chest in each picture, because the perception of the chest delineation is important when identifying the centre for the chest.



**Fig. 1 – Female chest.**

**The black cross indicates the correct hand position for cardiopulmonary resuscitation. (A) “The centre of the chest”; laypersons (white) versus healthcare professionals (black). (B) “Where to perform chest compressions”; laypersons (white) versus healthcare professionals (black). (C) “The centre of the chest” (black) versus “where to perform chest compressions” (white), for laypersons. (D) “The centre of the chest” (black) versus “where to perform chest compressions” (white), for healthcare professionals.**



**Fig. 2 – Male chest.**  
**The black cross indicates the correct hand position for CPR. (A) “The centre of the chest”; laypersons (white) versus healthcare professionals (black). (B) “Where to perform chest compressions”; laypersons (white) versus healthcare professionals (black). (C) “The centre of the chest” (black) versus “where to perform chest compressions” (white), for laypersons. (D) “The centre of the chest” (black) versus “where to perform chest compressions” (white), for healthcare professionals.**

### Data analysis

Image J software version 1.7.0 was used for data collection. Data points for the correct hand position, where participants would position their hands for chest compressions, and where they believed the centre of the chest is, were registered as coordinates in Microsoft Excel 2007. The recommended hand position for chest compressions, the middle of the lower half of the sternum, was used as a point of reference in the data analysis.<sup>4</sup> Subsequently, the distance between the obtained points for each of the following questions; “where would you perform chest compressions?” and “where is the centre of the patient’s chest?”, was calculated using Microsoft Excel 2007.

### Statistics

Based on a pilot study ( $n = 10$  healthcare professionals and  $n = 10$  laypersons), it was calculated that 42 participants in each group would be required to detect a difference of 2.5 cm between the correct and the observed point for chest compressions (significance level of 0.05 and a power of 90%). Data were tested for normality using D’Agostino & Pearson’s test. Normally distributed data are presented as mean  $\pm$  standard deviation, whereas data not normally distributed are presented as median (25% percentile; 75% percentile). Categorical variables are presented as  $n$  (%). Differences between groups with normally distributed data were tested with a 2-tailed t-test, and within-group comparisons with a paired t-test. Data not being normally distributed were compared using Wilcoxon Ranksum test (independent data) and Wilcoxon Signed Rank Test (correlated data).

**Table 1 – Baseline characteristics of study population.**

	Healthcare professionals (n = 50)	Laypersons (n = 50)
Age	36 $\pm$ 7	42 $\pm$ 13
Female sex	50 (100)	27 (54)
Profession		
Nurse	50 (100)	–
Office employee	–	23 (46)
Administration & IT	–	8 (16)
Craftsmen	–	8 (16)
Sales assistant	–	7 (14)
Kindergarten teacher	–	2 (4)
Student/unemployed	–	2 (4)
Education level		
Upper secondary school	0	8 (16)
Vocational secondary school	0	16 (32)
Higher education (<2–4 years)	49 (98)	22 (44)
Higher education (>4 years)	1 (2)	4 (8)
Previous BLS course	50 (100)	32 (64)
Most recent BLS course		
<1 years	23 (46)	0
1–3 years	19 (38)	0
>3 years	7 (14)	50 (100)
Unknown	1 (2)	0
BLS course provider		
Falck/Danish Red Cross	1 (2)	7 (12)
The Danish Army	0	6 (12)
At school/Nursing school	2 (4)	9 (18)
Workplace/the Hospital	47 (94)	3 (6)
Unknown	0	7 (14)
Trained instructor in BLS/ALS	4 (8)	0
Previously performed BLS		
Yes	44 (88)	2 (4)
<6 months	30 (68.2)	1 (50)
6 months–2 years	7 (15.9)	0 (0)
>2 Years	6 (13.6)	1 (50)
Unknown	1 (2.2)	0 (0)
Do you feel capable of performing CPR		
Yes	50 (100)	22 (44)

ALS = Advanced life support, BLS = Basic life support, CPR = cardiopulmonary resuscitation. Age is presented as mean years  $\pm$ SD and the remaining parameters as  $n$ (%).

P-values  $<0.05$  were considered statistically significant. Analyses were performed using GraphPad Prism ver. 6.00 for Windows (GraphPad Software, La Jolla, CA, USA).

## Results

A total of 102 persons were included in the study; 52 laypersons and 50 nurses. Two laypersons were excluded from the study due to CPR training within the previous 3 years. A total of 50 nurses (primarily from Departments of Cardiology) were included. Baseline demographics are shown in Table 1. All healthcare professionals were females, while the sex distribution among laypersons was 54% female and 46% male. In addition, differences in profession and educational level were present between the two groups (Table 1).

All healthcare professionals had previously completed a CPR course, whereas this was the case for 64% of laypersons. In total, 88% of healthcare professionals had previously performed real-life CPR, while this applied to 4% of laypersons. All healthcare professionals and 44% of laypersons felt capable of performing CPR.

### Where to perform chest compressions

When laypersons were instructed to obtain the correct hand position for chest compressions based solely on the instruction "Identify the point where you would perform chest compressions", they tended to identify a hand position further away from the recommended position compared to healthcare professionals. Most laypersons would place their hands too lateral (to the left) and too cranial, and some were too caudal (Figs. 1 B and 2 B and Table 2, part 2.1).

### Left nipple

The instruction "place the point on the patient's left nipple" was used as a positive control for the understanding of anatomical landmarks and the software program. In total, 3 healthcare professionals and 5 laypersons pointed out the right nipple instead of the left.

### Centre of the chest

In contrast, when laypersons and healthcare professionals were instructed to "Identify the centre of the patient's chest" they showed no significant difference in the ability to obtain the correct hand position for both the picture of the male and the female (Figs. 1 A and 2 A and Table 2, part 2.2). For both groups, there was a tendency to obtain a position too cranial.

### Anterior area of the chest

Fig. 3 shows planimetric drawings of the anterior area of the chest outlined by laypersons (A and C) and healthcare professionals (B and

D), respectively. Visual inspection of these figures show that both groups showed variations with regards to anatomical perception of the delineation of the chest, but healthcare professionals obtained a result with less variation.

### Where to perform chest compressions vs centre of the chest

When laypersons were asked to identify "the point for chest compressions" and "the centre of the chest" for the female patient, a significant difference was observed. On the contrary, no significant difference was found when laypersons were instructed to identify "the point for chest compressions" and "centre of the chest" for the male patient (Figs. 1 C and 2 C and Table 2, part 2.3).

For healthcare professionals, no significant difference was found for the female patient when asked to identify the point for chest compressions and "the centre of the chest" and ". In contrast, a significant difference was found for the male patient (Figs. 1 D and 2 D and Table 2, part 2.4).

## Discussion

This study demonstrates that laypersons and healthcare professionals have different perceptions of the chest anatomy and different perceptions of where to place the hands when performing chest compressions. However, we find that the instruction "place the heel of your hand in the centre of the chest" is reliable and accurate for both healthcare professionals and laypersons.

A prerequisite for adhering to the recommendation of placing the heel of the hand "in the centre of the chest" is an understanding of the chest shape. When looking at the planimetric drawings, laypersons showed a greater variation in outlining the anterior area of the chest for both the male and female patient when compared to healthcare professionals, thus suggesting a difference with respect to anatomical knowledge. Similarly, laypersons tended to perform chest compressions towards the left of the

## Table 2 – Results.

### 2.1. Point for chest compressions (PCC): healthcare professionals vs laypersons

PCC	Healthcare Professionals	Laypersons	P-value
Male thorax	27.5 ± 15.0 mm	36.7 ± 22.1 mm	0.03
Female thorax	18.3 (12.0;29.9) mm	44.9 (24.3;72.1) mm	<0.0001

### 2.2. Center of the chest (COC) identification: healthcare professionals vs laypersons

COC	Healthcare Professionals	Laypersons	P-value
Male thorax	33.9 (23.4;54.2) mm	37.6 (23.5;51.4) mm	0.57
Female thorax	20.6 (12.1;35.4) mm	19.9 (11.4;27.3) mm	0.50

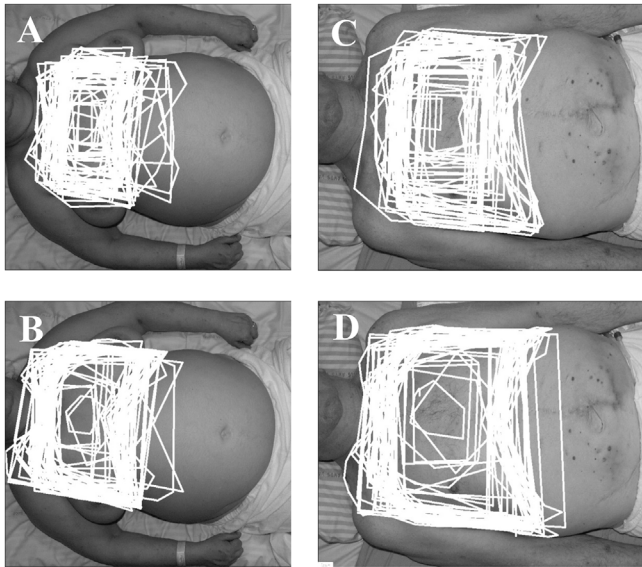
### 2.3. Center of the chest vs point for chest compressions for laypersons

Laypersons	COC	PCC	P-value
Male thorax	37.8 ± 19.3 mm	36.7 ± 22.1 mm	0.08
Female thorax	19 (11.4;27.3) mm	44.9 (24.3;72.1) mm	<0.0001

### 2.4. Center of the chest vs point for chest compressions for healthcare professionals

Healthcare Professionals	COC	PCC	P-value
Male thorax	33.9 (23.4;54.2) mm	25.0 (16.5;39.2) mm	0.001
Female thorax	20.16 (12.1;35.4) mm	18.3 (12.0;29.9) mm	0.09

COC = data from the instruction to point out the centre of the patient's chest, PCC = data from the instruction to place the point to perform chest compressions.



**Fig. 3 – Planimetric identification of the anterior area of the chest.**

**A: Anterior area of the female chest defined by the laypersons. B: Anterior area of the female chest defined by the healthcare professionals. C: Anterior area of the male chest defined by the laypersons. D: Anterior area of male chest defined by the healthcare professionals.**

sternum compared to healthcare professionals. This may be due to the lay public being aware that the heart is located in the left side of the thoracic cavity.

Interestingly, instructing healthcare professionals and laypersons using the ERC guideline (heel of the hand on the centre of the chest) without visual directions, resulted in no significant difference between laypersons and healthcare professionals in obtaining the correct hand position for CPR. One possible explanation is that “place the heel of your hand in the centre of the chest” does not require a deep understanding of anatomy, e.g., the location of the heart in the thoracic cavity.

Both groups tended to obtain a hand position too cranial, both when asked where to perform chest compressions and when asked to identify the centre of the chest. Importantly, compressions on the sternum would increase the intrathoracic pressure, which may not be the case with a hand position below the sternum being used by some of the laypersons.<sup>8</sup> However, several studies suggest that a hand-position too cranial would compress the ascending aorta or the left ventricular outflow tract, which could lead to lower systolic blood pressures and less effective chest compressions.<sup>9–12</sup>

Based on a previous study, we expected that laypersons, when instructed according to the ERC guidelines without visual directions, would tend to place their hand too lateral and caudal.<sup>6</sup> It is unknown whether the difference, when comparing to the previous study, is due to a different chest shape of the manikin or because participants tend to place their hands closer to themselves during simulated cardiac arrest.

Most research on CPR guidelines and CPR training has been performed using resuscitation manikins. These manikins normally represent anatomy corresponding to a normal weight, younger male. Importantly, this does not correspond to the typical person in cardiac

arrest being older and more obese.<sup>13,14</sup> Accordingly, the typical patient is more likely to be represented by the pictures used in this study.

Our results suggest a variance based on the gender of the patient in cardiac arrest. A significant difference between laypersons' identification of points for chest compression on the female patient before and after ERC guideline instructions without visual directions was observed. On the contrary, no significant difference was found when participants were instructed to identify points for chest compression on the male patient. This finding is consistent with a study by Kramer et al. showing that laypersons have different hand placement when performing CPR on a male manikin compared to a female manikin.<sup>15</sup>

For healthcare professionals, the opposite appeared to be the case; no significant difference was found for the female patient, while a significant difference was found for the male patient, perhaps explained by differences in demographic data among our study participants. It is reasonable to suggest that a gender difference regarding the perception of the female anatomy is an important factor when identifying points for chest compression. The importance of differences in gender for both victims and rescuers should be investigated in further studies. Also, female resuscitation manikins should be included when teaching CPR.

The ERC guideline is not only used in CPR training. It has also been applied in manuals, pamphlets and phone apps describing CPR techniques to the lay public. Often, no visual demonstration is provided in this material and it may be questioned whether laypersons can obtain the correct hand position based on verbal or written instructions only. In comparison, no visual instructions are provided during dispatcher-assisted CPR. Although dispatcher-assisted CPR can increase bystander CPR and increase survival from cardiac arrest,<sup>16</sup> only a few studies have investigated whether laypersons are able to obtain the correct hand position upon verbal or written instructions only.<sup>6,17–19</sup>

A study on dispatcher-assisted CPR suggested that the use of “the inter nipple line” as verbal instruction for hand placement resulted in a less caudal hand placement compared to “the centre of the chest” where 5/18 participants placed their hands in the epigastrium.<sup>18</sup> A similar pattern was found by another study showing a cranial tendency with the use of “the inter nipple line” as instruction when compared to “the centre of the chest” as instruction for laypersons.<sup>19</sup> Notably, one study found that dispatcher instructions for laypersons using both phrases, i.e., “Place one hand in the centre of the chest, right between the nipples, and the other on top” was superior (correct hand placement: 61%) to use of the current guideline recommendations only (correct hand placement: 36%), although not stating in which direction hand placement was wrong.<sup>17</sup>

The results of a more caudal hand placement when using the instruction of placing the hands on the centre of the chest is in contrast to our findings of a tendency to obtain a hand position too cranial when using this instruction. The difference is likely being explained by our use of pictures of cardiac patients of both genders with anatomical landmarks differing from the usual resuscitation manikins.

As shown in our study, healthcare professionals and laypersons show no significant difference in obtaining the correct hand position for CPR, when instructed according to the ERC guideline without visual directions, thus supporting the current guideline wording to be used as instruction in dispatcher-assisted CPR.

Previous studies have shown that necessary skills and knowledge of CPR are inadequate among the lay public, even months after CPR

training due to repaid deterioration of the acquired skills.<sup>20–22</sup> This is in contrast to the healthcare professionals where 84% had received CPR training within the last three years. Notably, the guideline recommendation of placing the hands on the centre of the chest was primarily based on studies of healthcare professionals or healthcare students, similar to a number of other guideline recommendations.<sup>4,5,7–9,23,24</sup> Our findings support that the current guideline recommendation for placing the heel of the hand in the centre of the chest can be used for both laypersons and healthcare professionals. However, the findings of different perceptions of chest anatomy and different perceptions of correct hand placement suggest that caution should be taken when extrapolating findings from healthcare professionals to laypersons in the evaluation of CPR science.<sup>24,25</sup>

## Limitations

We only compared nurses and laypersons, however the differences observed in perception of anatomy may be even more pronounced if medical students or medical doctors had been included, since doctors and medical students receive a more detailed education in anatomy and advanced life support. Further limitations include the use of digital pictures, instead of real persons, where it is possible to physically identify the sternum, rib curvature and ribs. However, the pictures used in this study are more representative for a real cardiac arrest patient when compared to the resuscitation manikins used in previous studies.<sup>5,7–9</sup> In addition, there was a weight variation (79 kg and 105 kg) in the patients in the digital pictures, which may have impacted on clearly delineating the borders of e.g. the patient's sternum and diaphragm. The randomization of the sequence of pictures for each participant makes a learning effect between the two pictures unlikely. All participating healthcare professionals were female nurses. Finally, participants were asked only to locate the centre of the chest and where they would perform compressions but not to "place the heel of their hand on the centre of the chest" as stated in the guidelines. Where study participants ultimately would place their heel of their hand on the chest was not investigated in the current study.

## Conclusion

Laypersons and healthcare professionals have different perceptions of the chest anatomy and where to perform chest compressions, suggesting that caution should be taken when extrapolating results from healthcare professionals to laypersons. The ERC 2015 guideline recommendations stating to place "the heel of your hand in the centre of the chest" seems understandable by both laypersons and healthcare professionals.

## Conflicts of interest

None to declare.

## CRediT authorship contribution statement

**Ann Mai Hindkjær Østergaard:** Methodology, Investigation, Formal analysis, Project administration, Writing - original draft,

Writing - review & editing. **Erik L. Grove:** Methodology, Investigation, Formal analysis, Supervision, Writing - review & editing. **Kasper Glerup Lauridsen:** Methodology, Writing - review & editing. **Bo Løfgren:** Conceptualization, Resources, Methodology, Investigation, Supervision, Project administration, Writing - review & editing.

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