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Radiological assessment of facial recess and correlation with surgical measurement in cochlear implantation

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Abstract

Background The facial recess (FR) is the crucial landmark in posterior tympanotomy approach which is the conventional approach for cochlear implantation surgery. This work aimed to measure the facial recess width and length radiologically and correlate these measurements with the surgical measurements in cochlear implantation procedure. An observational cross-sectional study was conducted on one hundred patients with sensorineural hearing loss prepared for cochlear implantation according to health insurance regulations. Patients included in the study were subjected to the following protocol: a routine ENT examination formed the initial part of the evaluation, audiological tests for adults and children were done, and the radiological evaluation for the patients included high-resolution computed tomography (HRCT) scanning [axial plane, oblique sagittal plane, and curved multiplanar reconstruction (MPR CT)]. These HRCT images were used to measure the facial recess width and length. Measurement of the FR width and length was done intraoperative by using a sterile ruler. Radiological measurements were correlated with the surgical measurements.

Results There was a statistically significant correlation between FR width surgically and FR width radiologically (p-value < 0.001). FR width measured in CT axial cuts, curved MPR images, and oblique sagittal cuts could predict FR width surgically. There was a statistically significant correlation between FR length surgically and FR length radiologically (p-value < 0.001). There was no statistically significant correlation between age and sex on one hand and surgical and radiological measurements on the other hand.

Conclusion Preoperative HRCT axial plane, oblique sagittal plane, and curved MPR CT can predict actual facial recess width and length.

Keywords Facial recess width, Facial recess length, Curved MPR CT, Oblique sagittal plane

Background

The traditional and most recommended approach for facilitating cochlear implantation is the posterior tympanotomy through facial recess, particularly when the electrode is put through the round window [1].

The facial recess (FR) is a triangular space defined medially by the mastoid segment of the facial nerve (FN), laterally by the chorda tympani nerve (CT), and superiorly by the incudal fossa [2]. The width of the FR can be regarded as normal if the distance between the external

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auditory canal (EAC) and the FN is greater than 2–3 mm. The FR often offers adequate exposure to the round window niche if there is enough width and the round window is positioned normally [3].

The importance of preoperative radiological imaging is emphasized as the boundaries of the facial recess and awareness of the related anatomy are important in the prevention of complications for example facial paralysis [4]. This work aimed to measure the facial recess regarding width and length radiologically and correlate these measurements with the surgical measurements during the cochlear implantation.

Methods

The current study was an observational cross-sectional study conducted on one hundred patients with sensorineural hearing loss (SNHL) prepared for cochlear implantation according to health insurance regulations. The patients were enrolled in the study from otorhinolaryngology departments of tertiary referral hospitals from May 2019 to June 2022. The study was conducted after the approval of the institutional review board. Informed written consent was provided by all participants or their parent or legal guardian in case of children under 16 years.

To be included in the study, every patient should be of the age of 1 year or more, with audiometric candidacy expressed as severe to profound SNHL with pure tone audiometry (PTA) $\geq$ 70 dB for ages 2–17 years and profound SNHL with PTA $\geq$ 90 dB for children aged 12–24 months. Speech recognition criteria included a limited benefit from binaural amplification trial after 3 months of usage as described by Farinetti, with word recognition tests like Multisyllabic Lexical Neighborhood Test and Lexical Neighborhood Test scores $\leq$ 30% for 2–17 years [5].

Patients with agenesis of the cochlea or the cochlear nerve, patients with severe mental disease, patients with acute or chronic otitis media and mastoiditis without eradication of the disease, patients with mental retardation incapable of cooperating with speech therapy, patients with cochlear rotation, and patients with surgical unfitness like uncontrolled medical diseases were excluded from the study.

Preoperative assessment

Every patient included in the study was subjected to the following protocol which was the same for adults and children. A routine ENT examination formed the initial part of the evaluation. An audiological test battery for adults consisted of audiometry, tympanometry, and speech perception tests. For younger children, play audiometry or visual reinforcement audiometry, tympanometry, and speech perception tests were used. Objective electrophysiological studies, such as auditory brain stem response and/or electrocochleography tests, were frequently employed to confirm the findings of behavioral hearing tests performed on young children.

The radiological evaluation for the patients included high-resolution computed tomography (HRCT) scanning which was required to determine any possible cochlear ossification and congenital malformations as well as anatomical landmarks. Radiological imaging was performed using an HRCT machine which was a Toshiba CT scanner Gantry, model COGT-022A (Toshiba Medical Systems corp., Tokyo, Japan). The CT scan data were acquired at 120 kV and 200 mA, and the imaging matrix was 512 $\times$ 512. The axial cuts were obtained parallel to the orbito-meatal baseline and viewed in the standard bone window settings. Coronal cuts were made in a plane perpendicular to axial images at 0.6 to 0.5 mm intervals. The oblique sagittal plane was done by using multiplanar reconstruction (MPR). Curved multiplanar reconstruction (MPR) computed tomography (CT) was done by a software application on an HRCT machine by scrolling through the axial plane and tracing the chorda tympani nerve from the posterior canaliculus to the branching point from the facial nerve.

These HRCT images were used to measure the facial recess width and length. Facial recess width was defined radiologically as the vertical distance between the vertical segment of the facial nerve and chorda tympani posterior canaliculus (maximum distance). It was measured in the axial cut, oblique sagittal cuts, and curved MPR CT (maximum width). It was measured from the anterolateral surface of the facial nerve to the posterior canaliculus of the chorda tympani nerve (maximum distance) (Fig. 1 A–C). Facial recess length was defined radiologically as the length of the facial nerve from the most superior point beneath the lateral semicircular canal to the chorda tympani branching point in the oblique sagittal plane and curved MPR CT (Fig. 2A, B). Magnetic resonance imaging (MRI) was used to assess in more detail the inner ear and the cochlear nerve. Study patients were subjected to psychological testing as a part of the preoperative assessment, to rule out any severe problems. A general clinical examination was performed to check the patient's general state of health.

Surgical technique

The surgical technique started with a retroauricular approach, cortical mastoidectomy, and posterior tympanotomy. The facial nerve and chorda tympani were used as landmarks to open the facial recess and mark the path of entry into the middle ear. The mastoid segment of the FN was skeletonized, and its relation to the

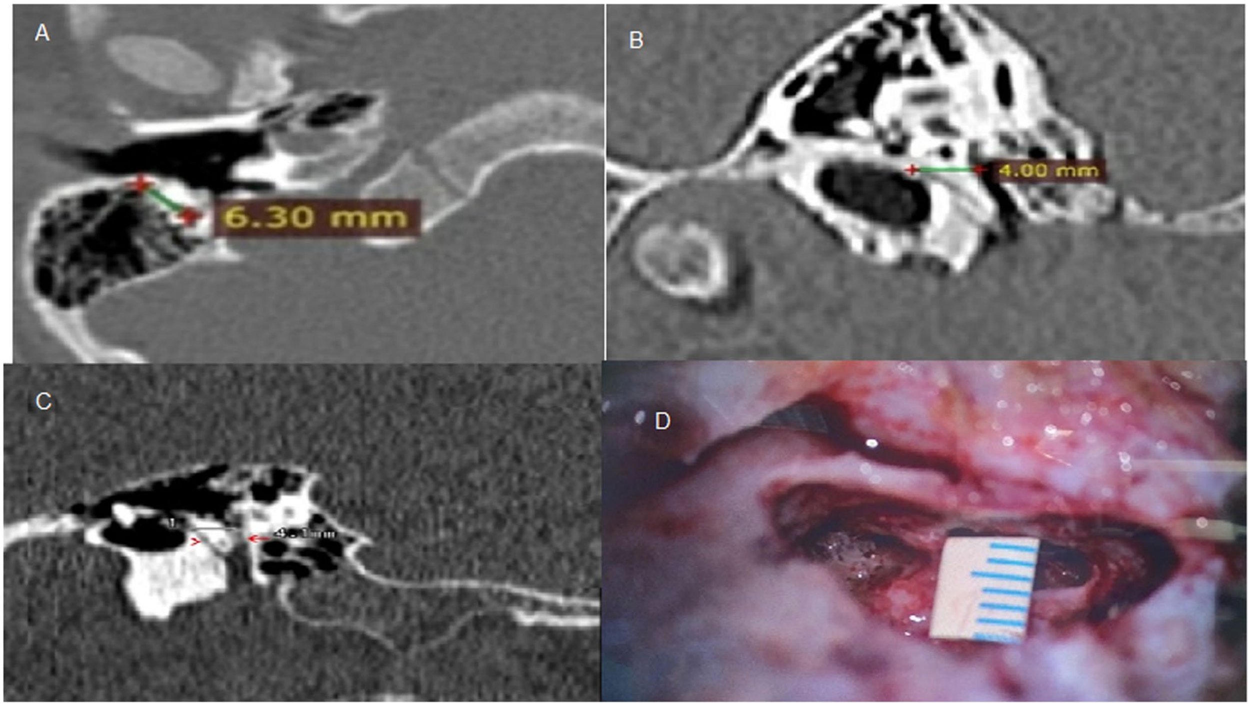

Fig. 1 **A** High-resolution computed tomography (HRCT) axial cut showing right (RT) facial recess width of 6.30, **B** HRCT oblique sagittal cut (MPR) showing facial recess width of 4.00 mm, **C** HRCT curved MPR image showing facial recess width of 4.1 mm, facial nerve (arrow), and chorda tympani (head arrow), and **D** intraoperative view showing right facial recess width of 4 mm

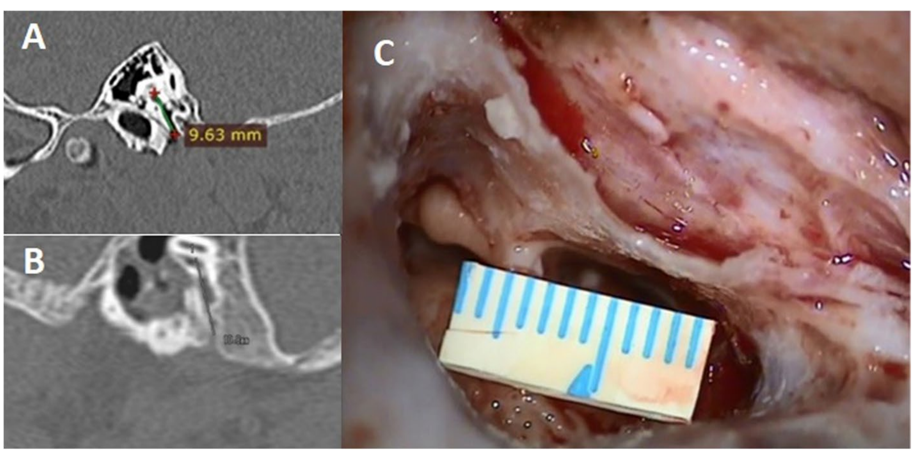

Fig. 2 **A** High-resolution computed tomography (HRCT) oblique sagittal cut showing a facial recess length of 9.63 mm (measured from most superior point of vertical segment of the facial nerve to branching point of chorda tympani), **B** HRCT curved MPR image showing a facial recess length of 10.8 mm (measured from most superior point of vertical segment of the facial nerve to branching point of chorda tympani), and **C** intraoperative view showing a facial recess length of 10 mm

dome of the lateral canal was identified, leaving a small incus bridge intact. Then, the chorda tympani nerve was dissected from the takeoff point of the FN up to the point where it entered the middle ear. The FR was thus delineated.

Measurement of the facial recess width and length was done by using a sterile ruler. The facial recess width was measured as the distance between the vertical part of the facial nerve and chorda tympani (maximum width) (Fig. 1D). The facial recess length was measured as the length of the facial nerve from the most superior point beneath the lateral semicircular canal to the chorda tympani branching point (Fig. 2C).

The seat for the implant was then created. The round window approach was used for electrode insertion, and then an intraoperative device function assessment was done. The wound is closed in layers and dressed.

Outcomes

The primary outcome measure was to define a simple and practical measurement method using preoperative CT to predict facial recess width and length. The secondary outcome measures were the correlation between age and sex on one hand and facial recess width and length on the other hand.

Statistical analysis

Data were collected, revised, coded, and entered into the Statistical Package for Social Science (IBM SPSS) version 23 (IBM Corp., Armonk, NY, USA). The quantitative data were presented as mean, standard deviations, and ranges when parametric and median and inter-quartile range (IQR) when data were found non-parametric. Also, qualitative variables were presented as numbers and percentages. The comparison between groups regarding qualitative data was done by using the *chi-square test* and/or *Fisher exact test* when the expected count in any cell was found less than 5. The comparison between two independent groups with quantitative data and parametric distribution was done by using an *independent t-test. Spearman correlation coefficients* were used to assess the correlation between two quantitative parameters in the same group. The confidence interval was set to 95% and the margin of error accepted was set to 5%. *p*-value was considered significant as when < 0.05 and highly significant (HS) when < 0.001.

Results

The present study included one hundred patients distributed as 56 (56.0%) females and 44 (44.0%) males with an age range from 1.7 to 33 years (Table 1). The mean FR width surgically was 4.44 ± 0.86 mm SD, the mean FR width radiologically in HRCT axial cuts was 4.51 ± 0.85 mm SD, the mean FR width radiologically in HRCT oblique sagittal cuts was 4.40 ± 0.82 mm SD, and the mean FR width with curved MPR CT of 4.49 ± 0.88 mm SD. The mean FR length surgically was 9.98 ± 0.97 mm SD, the mean FR length radiologically in HRCT oblique sagittal cuts was 9.87 ± 0.81 mm SD, and the mean FR length in HRCT curved MPR images was 9.87 ± 0.83 mm SD (Table 2).

There was a statistically significant correlation between FR width surgically and FR width radiologically in HRCT axial, oblique sagittal plane, and curved MPR images with a *p*-value of 0.001 (Table 3). There was a statistically significant correlation between FR length surgically and FR length radiologically in HRCT oblique sagittal cuts and curved MPR images with a *p*-value of 0.001 (Table 3). There was no statistically significant correlation between age and sex on one hand

Table 1 Descriptive for demographic data of the studied patients

Parameter		No. = 100
Age (years)	Median (IQR)	3 (2–5.2)
	Range	1.7–33
Sex	Female	56 (56.0%)
	Male	44 (44.0%)

IQR interquartile range

Table 2 Descriptive for clinical and radiological measurements of the studied patients

	Parameter		No. = 100
FR width (mm)	Clinical (mm)	Mean ± SD	4.44 ± 0.86
		Range	2–6
	Radiology axial cut (mm)	Mean ± SD	4.51 ± 0.85
		Range	2.2–6.45
	Radiology oblique sagittal cut (mm)	Mean ± SD	4.40 ± 0.82
		Range	2.23–6.01
	Curved MPR CT	Mean ± SD	4.49 ± 0.88
		Range	2.22–6.2
FR length (mm)	Clinical (mm)	Mean ± SD	9.98 ± 0.97
		Range	8–12
	Radiology oblique sagittal cut (mm)	Mean ± SD	9.87 ± 0.81
		Range	8.08–11.7
	Curved MPR CT	Mean ± SD	9.87 ± 0.83
		Range	8.02–11.7

FR facial recess, *MPR CT* multiplanar reconstruction computed tomography

Table 3 Correlation between surgical and radiological measurements of FR width and length

Parameter	*r*	*p*-value
FR width surgical		
FR width radiology CT axial cut (mm)	**0.917****	**0.001**
FR width radiology CT oblique sagittal cut (mm)	**0.870****	**0.001**
FR width curved MPR CT	**0.917****	**0.001**
FR length surgical		
FR length radiology CT oblique sagittal cut (mm)	**0.890****	**0.001**
FR length curved MPR CT	**0.846****	**0.001**

p-value > 0.05: non-significant; *p*-value < 0.05: significant; *p*-value < 0.01: highly significant, Spearman correlation coefficient. *FR*, facial recess; *MPR CT*, multiplanar reconstruction computed tomography and FR measurements either surgically or radiologically on the other hand (Table 4).

Discussion

In 1958, Jansen was the first to outline the posterior tympanotomy approach [6]. A thorough analysis of the facial recess is necessary due to the frequent use of posterior tympanotomy in ear surgeries and its relation to critical structures such as the facial nerve [7].

Radiological evaluation of the facial recess is done by using HRCT. In our study, we used HRCT with image reconstruction in an oblique sagittal plane by using multiplanar reconstruction (MPR) and curved MPR CT to measure the facial recess width and length. In addition, the radiological measurements of the facial recess were correlated with the surgical measurements which were done intraoperative during cochlear implantation. We used curved MPR CT for the first time in evaluating the facial recess in our study. With curved MPR CT, a tubular structure can be seen over its whole length in a single image.

In the present study, the width of the facial recess, which was measured radiologically in CT axial plane, CT oblique sagittal plane, and curved MPR CT ranged from 2.2 mm to 6.45 mm with mean ± SD 4.51 ± 0.85 in CT axial plane, 2.23 mm to 6.01 mm with mean ± SD 4.40 ± 0.82 in CT oblique sagittal plane, and 2.22 mm to 6.2 mm with mean ± SD 4.49 ± 0.88 in curved MPR CT.

This is consistent with the findings reported by Su et al. and Young et al. of FR width of 3.8 to 4.0 mm [8, 9] and similar to the finding described in Bettman et al. study's during which preoperative CT scans of the temporal bone were compared with the finding at the surgery to measure the dimension of the facial recess and the relationship between the facial recess and the cochlea. They found that the mean width of the facial recess was 4.5 mm at the level of the round window, with a standard deviation of 1.3 mm [10].

High-resolution computed tomography and MRI findings in patients being evaluated preoperatively for CI were graded on a 10-point scale by Vaid et al. The FR anatomy was considered as one of the parameters of difficulty encountered during CI, in which a narrow FR of less than 3 mm was considered unfavorable, whereas a wide FR of more than 3 mm was considered favorable [11].

In our study, the FR width ranged from 2.00 to 6.00 mm. These findings match the findings of Vaid et al. who found that an FR of < 3 mm is unfavorable, as in the cases with FR width < 3 mm, mobilization of the posterior external auditory canal wall was done by using a 0.5-mm bur superiorly at the attic and inferiorly just below the level of the round window, and the canal skin was kept intact and translocate the bone of the medial external auditory canal anteriorly together with its attached skin to improve visualization of the round window. Bone pate was used to fix the canal wall [12].

We found a positive correlation between the radiological measurements of the facial recess width (which was measured in CT axial plane, CT oblique sagittal plane, and curved MPR CT) and the surgical measurement, which was found to range from 2 to 6.00 mm with a mean of 4.44 mm ± 0.86 SD with p value 0.001; therefore, we could use the radiological measurement before cochlear implantation to predict the facial recess width.

Similar results were found by Hasaballah and Hamdy in their study, which involved 18 consecutive patients with severe to profound hearing loss who were candidates for cochlear implantation. They focused on oblique sagittal

Table 4 Correlation between age and sex on one hand and surgical and radiological measurements on the other hand among the studied patients

Parameter	Age (years)		Sex			
	r	*p*-value	Female Mean ± SD	Male Mean ± SD	Test value[a]	*p*- value
FR width surgical (mm)	− 0.159	0.114	4.42 ± 0.85	4.47 ± 0.89	− 0.265[a]	0.792
FR width radiology CT axial plane (mm)	− 0.165	0.101	4.46 ± 0.81	4.58 ± 0.91	− 0.704[a]	0.483
FR width radiology CT oblique sagittal plane (mm)	− 0.166	0.098	4.32 ± 0.78	4.50 ± 0.86	− 1.097[a]	0.275
FR length surgical (mm)	− 0.060	0.556	10.02 ± 0.94	9.93 ± 1.02	0.437[a]	0.663
FR length radiology CT oblique Sagittal plane (mm)	− 0.162	0.108	9.87 ± 0.75	9.88 ± 0.89	− 0.059[a]	0.953
FR width curved MPR CT	− 0.192	0.056	4.40 ± 0.85	4.60 ± 0.91	− 1.100[a]	0.274
FR length curved MPR CT	− 0.148	0.140	9.88 ± 0.80	9.86 ± 0.88	0.094[a]	0.925

p-value > 0.05: non-significant (NS); *p*-value < 0.05: significant; *p*-value < 0.01: highly significant

FR facial recess, *MPR CT* multiplanar reconstruction computed tomography

[a] Independent *t*-test

cut CT scan and its role in evaluating the course of the facial nerve, posterior tympanotomy width, and visibility of round window, and the results were correlated with the intraoperative finding. They found a statistically positive correlation between them [13].

Our work matches the findings of He et al. conducting a study of the anatomy related to CI guided by HRCT. They dissected six temporal bones according to the main steps of CI and scanned them in axial and semi-longitudinal planes by HRCT to observe the relation between anatomy and HRCT. The width of the FR in dissection was 3.13 ± 0.34 mm at the level of the round window and 4.12 ± 0.44 mm at the level of the oval window. The width of FR in HRCT was 3.20 ± 0.38 mm at the level of the round window and 4.14 ± 0.47 mm at the level of the oval window. The semi-longitudinal plane allowed the visualization of the whole course of the FN. There were no statistically significant differences between the dissection results and those of HRCT [14].

Our results are opposite to the finding reported by Bettman et al. They found no significant correlation between preoperative CT for FR width classification and the surgical finding. They explained their finding by the fact that facial recess and the cochlea were both measured on a viewing station and classified on printed films by 3 blinded and independent reviewers. The 3 reviewers had large interobserver variability. In 5 cases, neither an intuitive review of the CT scans nor viewing station measurements could predict any of the problems encountered during surgery [10].

We did not find any previous studies that used curved MPR CT in the assessment of the facial recess.

In our study, the facial recess length, which was measured radiologically, was found to range from 8.08 to11.7 mm a mean of 9.87 ± 0.81 mm in the CT oblique sagittal plane and range from 8.02 to11.7 with a mean of 9.87 ± 0.83 mm in curved MPR CT. The surgical measurement of the facial recess length was found to range from 8.00 to 12.00 with a mean of 9.98 ± 0.97 mm. There was a statistically significant correlation between the surgical measurement of FR length and the radiological measurements (curved MPR CT and CT oblique sagittal plane) of the FR length with a p-value < 0.0001. So, we can use the radiological measurement to predict the intraoperative measurement. Our findings are similar to the length of the facial recess, which was 9.7 mm from the most superior point beneath the lateral semicircular canal to the chorda tympani branching point the chorda tympani branching point to its most superior point as measured by Ozturk et al [15].

There was no statistically significant correlation between age and the FR measurements (width and length) surgically and radiologically. Our result is similar to the findings of some previous studies [16–18]. In the present study, there were 56 females and 44 males; there was no statistically significant difference in facial recess surgical and radiological measurements (width and length) and sex in the other hand. This is consistent with the finding made by Teszeler et al., who showed that gender-related differences in the measurement of the extended facial recess were not significant in their research of 100 male and 100 female patients using bilateral temporal bone HRCT scans [19].

The strength of our study was the novelty of the use of curved MPR CT in the assessment of facial recess width and length and the ability of facial recess measurement in multiple CT planes.

Conclusion

Preoperative HRCT axial plane, CT oblique sagittal plane, and curved MPR CT can predict actual facial recess width and length.

Abbreviations

CT	Chorda tympani
CI	Cochlear implantation
CT	Computed tomography
dB	Decibel
EAC	External auditory canal
FN	Facial nerve
FR	Facial recess
HRCT	High-resolution computed tomography
MRI	Magnetic resonance imaging
MPR CT	Multiplanar reconstruction computed tomography
PTA	Pure tone audiometry
SNHL	Sensory neural hearing loss

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Authors' contributions

EB provided the concept, with the definition of intellectual content; MH provided the study plan and conducted clinical studies and data analysis; MS conducted the clinical studies and data collection; SA conducted the clinical studies, data analysis, and manuscript editing; AE conducted the clinical studies, data collection, and data analysis. The authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Approval was obtained from Institutional Review Boards (IRB) of the Menoufia Faculty of Medicine and following the Declaration of Helsinki. After an explanation of all aspects of the study and being given the right to withdraw at any time, informed written consent was provided by all participants or their parent or legal guardian in case of children under 16 years.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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