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Role of dynamic sonography in ulnar nerve entrapment at elbow

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Abstract

Background: High-resolution ultrasound (HRUS) is a rapidly developing technology that is gaining popularity for the evaluation of the ulnar nerve.

Objective: To evaluate the role of dynamic HRUS for the detection of different abnormalities of ulnar nerve entrapment at the elbow.

Patients and Methods: Sixty-two elbows divided into 23 elbows with symptomatic and sonographic findings (symptomatic group), 39 elbows as a control group, which were further subdivided into 24 which were clinically and sonographically free (control group), and 15 subjects as a case nonmanifest group who were clinically free, but has sonographic findings (asymptomatic UNE group), were studied. The ulnar nerve cross-sectional area (CSA) was measured at the Guyon canal, mid-forearm, and maximal swelling (MS) point around the elbow. We assessed also the flattening ratio at the elbow by measuring the widest transverse and anteroposterior diameters during elbow extension and flexion.

Results: There was a statistically significant difference of the cross-sectional area and flattening ratio of the ulnar nerve at the elbow during extension and flexion between the three groups (symptomatic, case nonmanifest, and healthy control elbows) (P value = 0.05).

Conclusion: Dynamic HRUS is a highly accurate, sensitive diagnostic modality for the ulnar nerve entrapment syndrome at the elbow.

Keywords: Ulnar entrapment, Ultrasonography, Cross-sectional area, Flattening ratio

Introduction

Ulnar nerve entrapment (UNE) at the elbow is one of the most common entrapment neuropathies. The diagnosis basically relies on the combination of both clinical and electrodiagnostic techniques [1]; however, in many cases, they might provide insufficient or inaccurate data that may be misleading and cause delay in patient's diagnosis.

Electrophysiological false negative results may result from the fact that nerve conduction studies may fail to localize and diagnose ulnar nerve lesions with selective fascicular or pure sensory fiber involvement. Besides, ulnar nerve displacement at the elbow can also cause errors in distance measurements with overestimated nerve conduction velocities, and in those instances, imaging is often used to confirm the diagnosis [2].

Being a non-costly, fast, available, and non-invasive technique for the assessment of musculoskeletal disorders including evaluation of the elbow joint abnormalities related to or causing UNE syndrome, high-resolution ultrasound (HRUS) has gained increasing popularity as a diagnostic tool for musculoskeletal assessment [3]. According to previous studies, the cutoff point of the cross-sectional area of the ulnar nerve which is 10 mm^2 or higher proves its sensitivity and specificity of more than 88% for cubital tunnel syndrome diagnosis [4]. The cutoff value for the cross-sectional area of the asymptomatic ulnar nerve is suggested by Thoirs and his colleagues [5] to be 9 mm^2, derived as the upper limit of the 95% confidence interval. Also, Patel and his colleagues [6] recommend the use of the cross-sectional area (CSA) rather

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than the flattening ratio as it does not change with change of angle at the elbow.

Factors such as technical developments and improvements, increased experience, and detailed knowledge of elbow anatomy and its pathologic conditions together with awareness of different sonographic pitfalls, limitations, and artifacts have significantly improved sonographic elbow assessment results.

Study design and population

Our case-control study was performed between January and July 2015; patients were referred to the Radiology Department, or Neurosonology Unit in the Neurology Department, Faculty of Medicine, Cairo University, for HRUS of the elbow from neurology specialists.

The study was approved by the Neurology Department Faculty of Medicine, Cairo University Ethical Committee, and an informed consent to participate in the study was obtained from all subjects.

A total of 62 elbows were examined, and 39 were assigned as the healthy control group without any clinical symptoms or signs, but surprisingly out of the 39 control elbows, 15 limbs which had no previous signs or symptoms were found to have sonographic features suggestive of UNE and therefore classified as a separate subgroup named asymptomatic UNE group while 24 limbs had no symptoms or sonographic features of UNE at the elbow and were classified as a non-entrapment control group; the remaining 23 elbows were limbs with both symptoms and sonographic features of UNE and were assigned to the symptomatic UNE group.

Inclusion and exclusion criteria

Limbs were enrolled in the symptomatic UNE group if the participant had typical signs and symptoms of UNE syndrome, with no prior history predisposing to UNE at a site other than the elbow (e.g., shoulder or wrist pain), and had an electrophysiologically confirmed diagnosis of UNE for that limb, and were excluded in case of acute trauma to the elbow or if any surgical procedures for UNE was previously performed.

Methods

Static and dynamic grayscale ultrasound and Doppler examination of the ulnar nerve using the 6–7.5-MHz linear array transducer for the musculoskeletal system, Logiq P5, GE Medical Systems, USA ultrasound device, were performed for all participants.

Examination technique

For patient position, patients were instructed to either lie supine or sit with their arms abducted and externally rotated. Images were obtained while the elbow is fully extended then in different degrees of flexion.

Greyscale sonography was done using static and dynamic techniques for examination of the ulnar nerve at the elbow.

The cross-sectional area (CSA) of the ulnar nerve was measured circumferentially by direct manual tracing just inside the hyperechoic rim of the nerve with the transducer perpendicular to the nerve to ensure that the smallest and most accurate CSA was being obtained. Ultrasound was used to scan the entire ulnar nerve segment across the elbow and other common sites of nerve entrapment along the length of the nerve (Figs. 1, 2, and 3): (1) 2 cm proximal to the tip of the medial epicondyle, (2) tip of the medial epicondyle, (3) just at the entrance of the cubital tunnel (between the two heads of flexor carpi ulnaris (FCU) muscle, and (4) 2 cm distal to the tip of the medial epicondyle (in the FCU muscle).

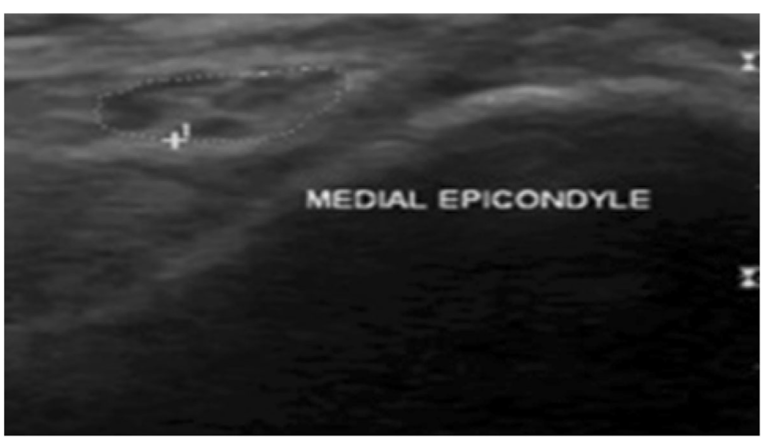

Fig. 1 Transverse scan of the ulnar nerve at the retro-epicondyle groove. CSA (cross-sectional area) measured using a direct tracing method excluding the epineurium [5]

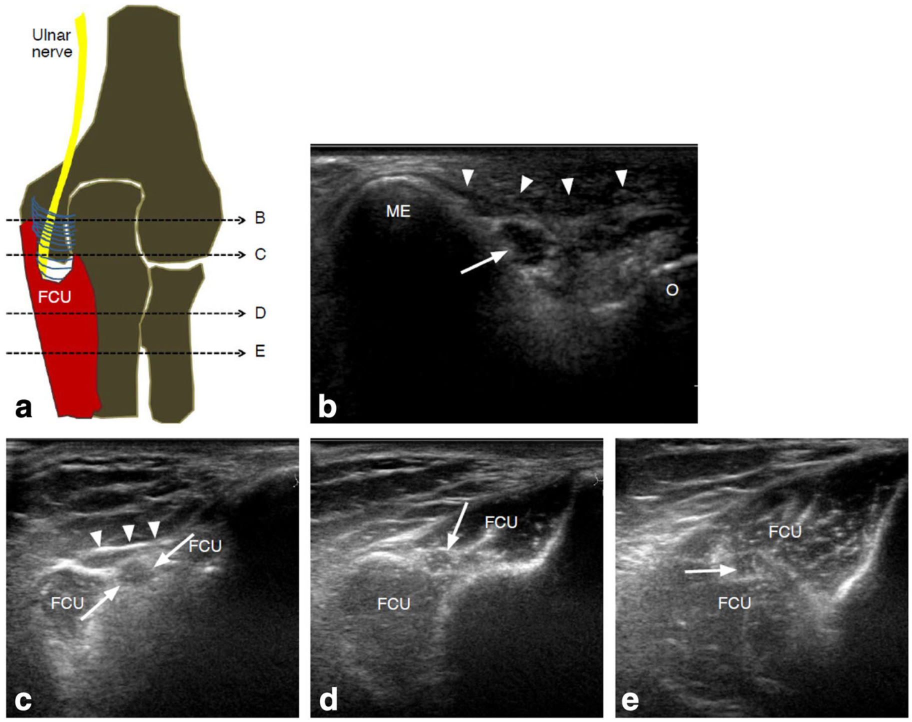

Fig. 2 The schematic representation and transverse sonograms of the normal ulnar nerve in the cubital tunnel and the proximal forearm

The CSAs of ulnar nerves with two or more fascicles were calculated as the sum of the individual measurements of the CSA of each fascicle [4].

The flattening ratio of the ulnar nerve at the elbow was obtained by measuring the widest transverse and anteroposterior cross-sectional nerve diameters (i.e., long and short axes) on axial images obtained by a direct tracing method during elbow extension and flexion. To obtain the proper axial images, the probe is placed in a plane traversing the olecranon process (OLE) and the medial epicondyle (ME) in full extension then during elbow flexion. (Images clearly showed the osseous floor of the cubital tunnel, the medial epicondyle, the olecranon process, and the ulnar nerve in a cross section).

The nerve was also assessed in terms of its mobility in association with elbow flexion. The patient was instructed to abduct and internally rotate his arm while the elbow is extended; at first, the probe was placed transversely between two bony landmarks: the medial epicondyle of humerus and the olecranon process of the ulna on the posteromedial aspect of elbow, then the patient was asked to flex his elbow gradually till 90° and 120° and the movement of ulnar nerve within the cubital groove was assessed in relation to the medial epicondyle. The nerve was categorized as stable if it remained posterior to the medial epicondyle, subluxing if it moved to the level of the medial epicondyle, or dislocating if it moved anteriorly to the medial epicondyle.

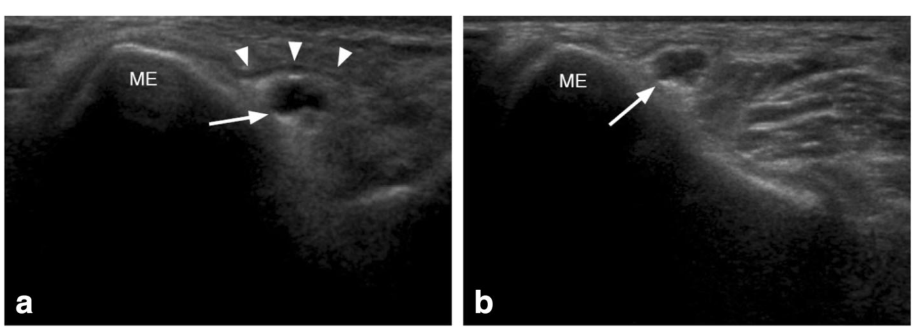

Fig. 3 The ulnar nerve location for different elbow positions. (**a**) anatomy of the ulnar nerve. (**b**) ulnar nerve by ultrasound while elbow and upper limb in rest postion

Table 1 Cross-sectional area (CSA) of the ulnar nerve in the asymptomatic ulnar nerve entrapment (UNE) group and the symptomatic UNE group compared to the control group

		Control group	Asymptomatic UNE group	*P* value	Symptomatic UNE group	*P* value
At elbow extension (cm^2)	Range	0.03–0.1	0.03–0.21	0.16	0.04–0.23	0.001
	Mean ± SD	0.06 ± 0.02	0.06 ± 0.04		0.10 ± 0.05	
At elbow flexion (cm^2)	Range	0.03–0.09	0.03–0.23	0.37	0.03–0.21	0.005
	Mean ± SD	0.06 ± 0.02	0.07 ± 0.05		0.09 ± 0.05	
Above elbow (cm^2)	Range	0.03–0.08	0.03–0.06	0.23	0.04–0.19	0.12
	Mean ± SD	0.05 ± 0.01	0.05 ± 0.01		0.06 ± 0.03	
Below elbow (cm^2)	Range	0.03–0.06	0.03–0.06	0.14	0.03–0.18	0.62
	Mean ± SD	0.05 ± 0.01	0.05 ± 0.01		0.05 ± 0.03	

The purpose of this study was to evaluate the role of dynamic high-resolution ultrasonography in the detection of different abnormalities including both the causes and sequelae of ulnar nerve entrapment at the elbow.

Statistical methods

The data were coded and entered using the statistical package SPSS version 15. The data were summarized using descriptive statistics, and statistical differences between groups were tested using the chi-square test for qualitative variables while the nonparametric Mann-Whitney test and Kruskal-Wallis test were used for quantitative variables which are not normally distributed.

For the ethical statement, the ethical committee of the Faculty of Medicine, Cairo University, has allowed this study.

Results

Ages of our study population ranged from 14 to 55 with a mean of 35 years. The mean cross-sectional areas (CSAs) of the ulnar nerve at, above, and below the elbow in all groups are illustrated in Table 1. The CSA of the ulnar nerve in the symptomatic manifest group has significant enlargement (P value = 0.05) than in the control group, but does not have significance above or below the elbow.

The flattening ratio of the ulnar nerve in the symptomatic group during elbow extension and flexion was significantly increased than in the control group, but no significant affection between the nonmanifest group and the control group (Table 2).

The ulnar nerve echogenicity was preserved in all control subjects; meanwhile, it was statistically significantly lost in 13 (56.5%) elbows of the symptomatic UNE group. The presence of UNE syndrome findings is displayed in both UNE groups.

Four (26.7%) out of 15 in the nonmanifest group had subluxation, and 11 (73.3%) had dislocation, while 7 (30.4%) in the symptomatic manifest group had subluxation, 12 (52.2%) had dislocation, and 4 (17.4%) had other abnormalities as synovial osteochromatosis or aberrant ulnar artery. Twelve (50%) of the control group showed a medial shift of the ulnar nerve within the cubital groove with a mean of 2.4 ± 0.6 mm and a range of 1.3 to 3 mm not reaching the medial epicondyle which is considered normal.

The following figures are examples for two cases: Figs. 4 and 5.

Discussion

HRUS is a cheap and non-invasive imaging modality that has become an interesting adjunct to electrodiagnostic studies in the evaluation of entrapment neuropathies [7]. Currently, magnetic resonance imaging (MRI) is the most commonly used imaging tool in the diagnosis of ulnar nerve entrapment; however, it is expensive, is time consuming, and allows only a segment of the nerve to be imaged at any given time [8].

In this study, dynamic HRUS examination of the ulnar nerve in the control group revealed the reference values of different ulnar nerve parameters that could be used for the ultrasonographic diagnosis and follow-up of the ulnar

Table 2 The ulnar nerve flattening ratio in the asymptomatic ulnar nerve entrapment (UNE) group and the symptomatic UNE group compared to the control group

		Control group	Asymptomatic UNE group	*P* value	Symptomatic UNE group	*P* value
Extension (cm^2)	Range	1.1–3.4	1.0–3.6	0.03	1.0–3.1	0.08
	Mean ± SD	1.9 ± 0.5	2.2 ± 0.6		1.6 ± 0.6	
Flexion (cm^2)	Range	1.2–4.6	2.1–6.8	0.001	1.0–6.8	0.004
	Mean ± SD	2.1 ± 0.8	3.9 ± 1.3		3.7 ± 1.8	

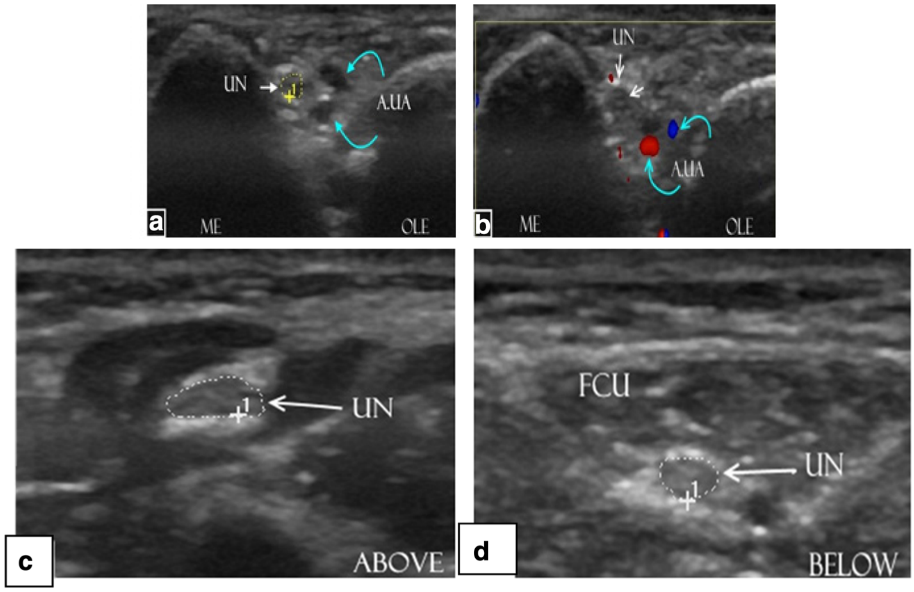

Fig. 4 Dynamic high-resolution ultrasound was done. **a** Transverse view of the cubital groove shows average CSA of the ulnar nerve (UN) within the cubital groove; two adjacent rounded anechoic structures are seen within the groove (curved green arrows). **b** Doppler examination of the cubital groove shows the aberrant ulnar artery (A.UA) and its vena comitans within the groove adjacent to the ulnar nerve. **c** Cross-sectional area of the ulnar nerve (UN) above the elbow (white arrow) which appears swollen evidenced by its increased CSA. **d** Cross-sectional area of the ulnar nerve (UN) below the elbow (white arrow) shows it is returning to normal. FCU = flexor carpi ulnaris muscle

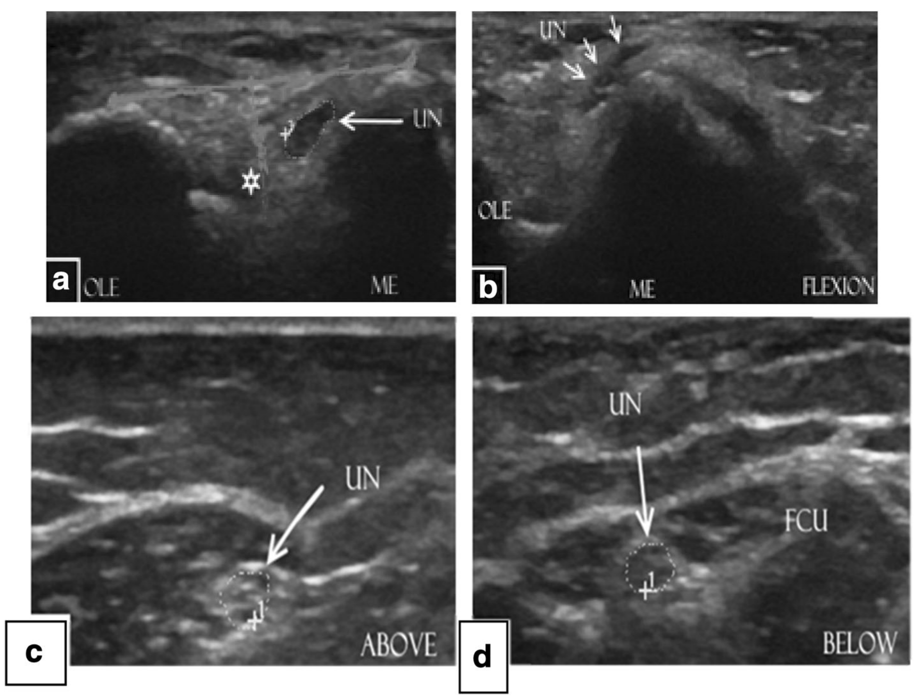

Fig. 5 Dynamic high-resolution ultrasound was done. **a** Ulnar nerve (white arrows) is seen within the cubital groove during elbow extension, **(*)** representing the cubital groove floor. **b** Dislocated ulnar nerve (white arrows) beyond the medial epicondyle during sequential elbow flexion. Average CSA of the ulnar nerve (UN). ME = medial epicondyle. OLE = olecranon process. **c** Cross-sectional area of the ulnar nerve (UN) above the elbow (white arrow). **d** Cross-sectional area of the ulnar nerve (UN) below the elbow (white arrow). FCU = flexor carpi ulnaris muscle

nerve lesions. The mean CSA of the nerve 2 cm above the elbow is $0.05 \pm 0.01\ cm^2$, 2 cm below the elbow is $0.05 \pm 0.01\ cm^2$, at the elbow in extension is $0.06 \pm 0.02\ cm^2$, and at the elbow in flexion is $0.06 \pm 0.02\ cm^2$. This in agreement with the study of Yalcin and his colleagues and also that of Jacob and his colleagues who [9, 10] reported that the ultrasonographic reference values of the ulnar nerve cross-sectional areas at the common areas of nerve entrapment revealed the mean ulnar nerve cross-sectional area was $0.05 \pm 0.01\ cm^2$ at 2 cm proximal to the medial epicondyle, $0.06 \pm 0.01\ cm^2$ at the medial epicondyle, and $0.05 \pm 0.01\ cm^2$ at 2 cm distal to the medial epicondyle (inside the flexor carpi ulnaris). But this was against the study which indicates that the cutoff value of the cross-sectional area of the asymptomatic ulnar nerve is $0.09\ cm^2$, derived as the upper limit of the 95% CI of the mean, and subject to sensitivity and specificity testing [5].

This investigation showed changes affecting the ulnar nerve echogenicity and echotexture in patients with UNE syndrome, in which the nerve becomes swollen and more hypoechoic with partial or complete loss of its fascicular pattern. In some cases, such changes may be the only and early diagnostic criteria of UNE especially in asymptomatic individuals detected by the high-resolution ultrasonography.

Also, Okamoto and his colleagues [11] confirmed a correlation between the severity of palsy and the echotexture and diameter of the major axis of the ulnar nerve indicating that the ulnar nerve swells with progressive stages of the palsy with partial or total loss of its normal fascicular pattern. However, some cases exhibited unusual and characteristic morphological changes.

CSA and flattening ratio (FR) measurements demonstrated significant differences between nerves with and without UNE especially during elbow flexion with $P = 0.005$ and $P = 0.004$ for nerve CSA and FR respectively in which both are less than $P < 0.05$. Same results were found in a study that proved the mean CSA and the mean flattening ratio of the ulnar nerve were significantly different at 90° of elbow flexion than elbow extension [6].

This also was in agreement with study of Thoirs and his colleagues, also Okamoto and his colleagues**,** who reported that the flattening ratio in elbow flexion increased in subluxated and dislocated nerves to a normal one and the differences between each ratio were significant whereas there was no significant difference between each ratio in elbow extension [5, 11].

But this was against the study done by Kim and his colleagues [12] who proved that the measurement of the CSA of the ulnar nerve taken at a site inferior to the medial epicondyle (about 2 cm) was significantly larger when made in elbow extension than when made in elbow flexion.

The difference may be explained by the alteration in the length of the path of the nerve that occurs with elbow flexion and subsequent changes in the nerve shape that occur to accommodate the altered nerve path.

In conclusion, dynamic HRUS is a highly accurate, sensitive diagnostic modality for the ulnar nerve entrapment syndrome at the elbow; we are able to detect ulnar nerve compression syndromes and its abnormalities.

Abbreviations
CSA: Cross-sectional area; FCU: Flexor carpi ulnaris; HRUS: High-resolution ultrasound; MS: Maximal swelling point; OLE: Olecranon process; UNE: Ulnar nerve entrapment

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available due to current Cairo University regulations & Egyptian legislation but are available from the corresponding author on reasonable request and after institutional approval.

Authors' contributions
HA and HH contributed to the research idea and conception. HA, HH, MM, AM, and SY contributed to the data acquisition, data analysis, interpretation, and manuscript writing and review. All authors read and approved the final manuscript.

Ethics approval and consent to participate
The aim and procedures of the study were explained to every participant and an informed consent was obtained before being enrolled in the study. The study was approved by the ethical committee of the Faculty of Medicine; Cairo University has allowed this study. Date of approval on 23rd February 2015 and final approval of whole work on 18th of July 2017, but the reference number of approval is not available.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Publisher's Note

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