Artifacts of Capturing Unintentional RF Energy Transfer During *In Vitro* Tonsillectomy

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***Abstract*—We have recently reported unintentional RF energy transfer to metal-based mouth retractor during tonsillectomy. Use of a highly sensitive current sensor to quantify this unintentional energy ends up capturing: (a) unintentional RF current coupled to the mouth retractor, (b) current flowing through the wire and probe of the electrosurgical equipment, and (c) current following through tissue during firing. The latter two are artifacts and hence undesired. In this work, we evaluate these artifacts via *in vitro* tonsillectomy experiments in presence and absence of mouth retractor. Our study shows that artifacts can lead to an overestimation of the unintentionally coupled current by 4.3, 2.6, and 2 times for power levels of 10 W, 20 W, and 30 W set at the electrosurgical generator, respectively. Hence, we illuminate the need for careful experimental design in future to eliminate such artifacts.**

I. Introduction

Tonsillectomy is a surgical procedure that involves removing the tonsils from throat [1]. One of the common techniques to perform this surgery is monopolar electrosurgery [2]. This involves firing of high RF power (in the range of few KHz) via a firing probe to heat and destroy the tonsil. Concurrently, a metal-based mouth retractor is used to keep the mouth open, while a grounding pad is connected to the human body to complete the current path. In doing so, current flows from the electrosurgical unit to the firing probe, and then into the tonsil where most of it is consumed in the form of heat. The remaining part goes back through the human body to the grounding pad which is connected back to the electrosurgical unit.

A common post-operative symptom associated with tonsillectomy is dysgeusia (distortion in sense of taste) [3], the reasons of which are still unknown. Our previous studies [4], [5] showed that RF current flowing in the vicinity of the metal-based mouth retractor can lead to unintentional RF energy transfer upon the retractor. Because of direct contact of the mouth retractor with the tongue, unintentional RF energy transfer could be the cause behind dysgeusia.

Our work in [4] and [5] used a highly sensitive current sensor to capture the unintentional RF energy transfer upon the mouth retractor. However, current sensed by the sensor had an intrinsic artifact in terms of the magnitude of current captured. Specifically, given its high sensitivity, the sensor ended up capturing not just the current induced on the mouth retractor,

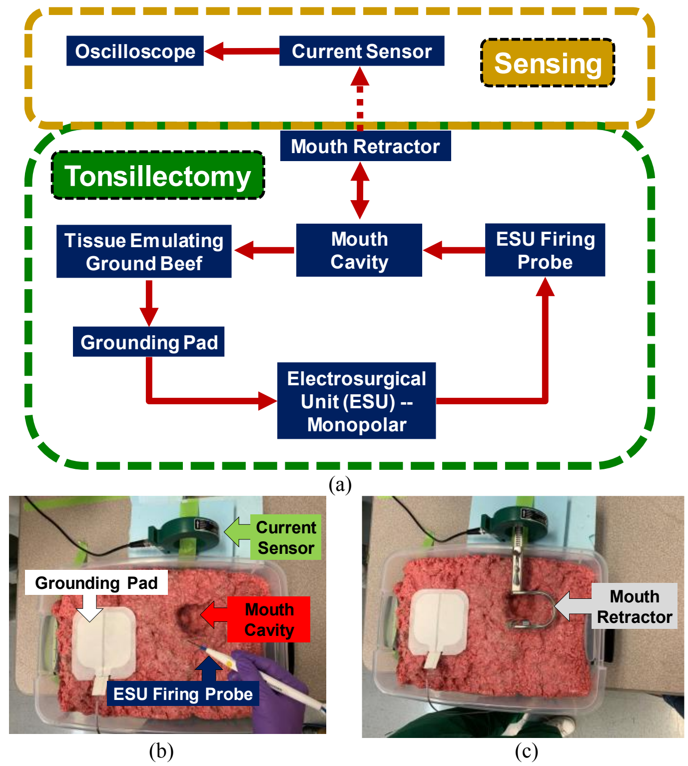

Fig. 1. (a) Schematic of experimental set-up which can be divided into two broad categories – Tonsillectomy and Sensing. Solid arrow lines depict physically connected entities or part of same entity, while dashed arrows depict no physical connection. (b) Experimental set-up without mouth retractor. (c) Experimental set-up with metal-based mouth retractor.

but also: (a) current flowing in the wires and firing probes of the electrosurgical unit, and (b) current flowing through tissue during firing. These two are artifacts and do not contribute to the unintentional RF energy transfer.

In this work, we: (a) introduce and quantify the above artifacts, (b) provide a solid understanding towards using a more accurate and reliable measurement set-up in future, and (c) confirm that there is, indeed, unintentional RF energy transfer upon the mouth retractor despite the presence of artifacts. To this end, an *in vitro* study is performed with and without the mouth retractor. Current sensed without the mouth retractor represents artifacts and can be readily removed from the total current

TABLE I. SUMMARY OF EXPERIMENTAL RESULTS.

Power (in W)	Average Current (pk-pk) (mA)			Overestimation due to artifact (x/(x-y))
	With mouth retractor (x)	*Without mouth retractor (artifact) (y)*	*Actual transfer to mouth retractor (x-y)*	
0 (Noise Floor)	4	4	-	-
10	27.44	21.08	6.36	4.3
20	36.4	22.52	13.88	2.6
30	45.68	23.2	22.48	2.0

sensed with the mouth retractor to identify the actual unintentional RF current induced on the mouth retractor.

II. EXPERIMENTAL SET-UP

Our *in vitro* experiment is described in Fig. 1(a) and consists of a set-up without a mouth retractor (Fig. 1(b)) and a set-up with a mouth retractor (Fig. 1(c)). Each set-up consists of two parts:

1) Tonsillectomy. The tonsillectomy part entails the electrosurgical unit (ESU) which is the source of RF power (Monopolar, Force 2 from Valleylabs), a firing probe connected to the ESU to fire towards the tonsil (Fig. 1(b)), ground beef emulating the average human tissue properties (Fig. 1(b) and (c)), a mouth cavity that is artificially made within the ground beef (Fig. 1(b) and (c)), a metal-based mouth retractor placed within the mouth cavity (Fig. 1(c)) and a grounding pad placed on the ground beef to complete the current path back to the ESU (Fig. 1(b) and (c)).

2) Sensing. The sensing part consists of a current sensor (Pearson Model 2100 [6]) (Fig. 1(b) and (c)) and an oscilloscope to record the current sensed by the sensor. The current sensor is kept in the close vicinity of the mouth retractor such that they are not touching each other (Fig. 1(c)). To create the experimental set-up without the mouth retractor, the latter is carefully removed such that the remaining set-up is undisturbed (Fig. 1(b)).

III. MEASUREMENTS AND RESULTS

Measurements are performed with (Fig. 1(c)) and without (Fig. 1(b)) the mouth retractor for three different RF power levels, 10W, 20W and 30W. As a starting point, the noise floor is recorded for both cases: with and without the mouth retractor. Five sets of measurements are then taken for each power level; each time, we measure the current sensed by the current sensor on the oscilloscope when the ESU probe fires inside the mouth cavity. Results for average peak-to-peak current detected by the current sensor along with the noise floor are summarized in Table I. Standard deviation with the mouth retractor is 2.96mA, 5.16mA, and 6.41mA for 10W, 20W, and 30W respectively. Without the mouth retractor, the standard deviation is 10.2mA, 4.31mA, and 2.87mA for 10W, 20W, and 30W respectively. Values obtained with and without mouth retractor are labeled as 'x' and 'y' in Table I, respectively, to depict the subsequent operations performed in other columns of the table.

The average readings corresponding to 'y' represent the undesired artifacts. This is subtracted from 'x' which represents the total current (artifacts plus current coupled on the mouth retractor) to obtain the actual current coupled to the mouth retractor ('x-y'). The latter value corresponds to true unintentional RF energy transferred to the mouth retractor. The last column of Table I ('x/(x-y)') depicts the number of times this unintentional transfer would be overestimated if the artifacts were not taken into account.

Here, it is worth noting that the magnitude of current reported in [4] and [5] is relatively high compared to the magnitude of total current ('x' of Table I) measured here. This is due to the ESU location and the way the firing probe approaches the mouth cavity. In [4] and [5], the ESU was placed on the same side as that of the current sensor and oscilloscope. By contrast, in this study, it was placed on the opposite side of the current sensor and oscilloscope (i.e., here, the mouth cavity lies in between the ESU unit and the current sensor). Such arrangement reduces coupling to the current sensor that could be caused due to wire running from the ESU to the firing probe. That is, in an ideal measurement set-up, apart from accounting for artifacts, the sensing set-up should also be placed opposite to the tonsillectomy set-up with respect to patient's mouth.

IV. CONCLUSION

In vitro tonsillectomy experiments were conducted with and without a metal-based mouth retractor. Our results showed that artifacts in the measurement set-up could overestimate the unintentional current transferred to the mouth retractor by 4.3, 2.6 and 2 times for power levels of 10W, 20W, and 30W respectively. Apart from changes in the measurement set-up needed to cater to these artifacts, other factors that can lead to more reliable and accurate measurements were also discussed. Finally, it was confirmed that despite presence of artifacts, unintentional transfer of energy to metallic mouth retractor is indeed real. This study will be useful in enabling a more accurate measurement set-up for future *in vivo* investigations. The ultimate aim is to study the post-operative adverse effects of such unintentional RF energy transfer.

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