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ENDOCRINE METHODS AND TECHNIQUES

Transmucosal oxygen tension of the clitoris: a new parameter for future investigations of the sexual, metabolic, and cardiovascular health of women

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Abstract

Background Several studies suggested that abnormalities in tissue perfusion of external genitalia and vagina can lead to female sexual dysfunctions (FSDs) and can be associated to metabolic and cardiovascular risk factors. However, there are some technical difficulties in assessing these abnormalities. The measurement of oxygen partial pressure is a noninvasive method to measure oxygen partial pressure (pO_2) at the skin surface to assess tissue perfusion. The aim of this study was to evaluate whether transmucosal oxygen tension ($TmPO_2$) can be measured at the mucosal surface of clitoris and whether the measurements are reliable.

Methods $TmPO_2$ was measured in six young healthy women by using a device to measure transcutaneous pO_2 on the skin and by choosing a small sensor, usually used for newborns. The identical procedure for the detection of pO_2 at the skin surface was used.

Results The mean value of $TmPO_2$ was 42.3 mmHg (range: 24.1–53.4 mmHg). All the trend curves of the $TmPO_2$ showed the same behavior: after a stabilization time, there was a stable pO_2 (plateau phase) that corresponds to the $TmPO_2$ of the clitoris. These curves had a similar trend to those recorded at the skin surface.

Conclusions $TmPO_2$ can be easily measured at the mucosal surface of clitoris. Large epidemiological studies in healthy and unhealthy women and in women with FSD are needed to establish both the normal range of $TmPO_2$ and the meaning that different values of $TmPO_2$ can have on sexual and general health of the women.

Keywords Female sexuality · Oxygen tension · Cardiovascular risk · Clitoris · Tissue perfusion

Introduction

Female sexuality depends on many factors, including features of the hemodynamics of external genitalia and vagina [1]. Indeed, normal female sexual response needs integrity of vascular districts [1]. An increase in blood flow due to changes in hemodynamics of clitoris and vagina is important for arousal and lubrication [1]. On the other hand, abnormalities of vascular districts of clitoris and vagina can lead to female sexual dysfunctions (FSDs) [2], in particular to diminished vaginal lubrication, delayed vaginal engorgement, reduced libido and arousal, and possible dyspareunia [1, 2]. Recent data suggest that both FSD and associated hemodynamic changes are linked to several cardiometabolic risk factors, such as obesity, diabetes, hyperlipidemia, hypertension, and metabolic syndrome [3–6] Because of these strong associations a greater cardiovascular risk has been hypothesized in women with FSD; in

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addition, vascular abnormalities of clitoris and vagina have been suggested as potential markers of an increased risk for cardiovascular events. Nevertheless, a direct association of female sexual health and modifications in clitoral blood flow with metabolic and cardiovascular risk are not well defined.

On the contrary, in men the strong association between abnormalities in the hemodynamics of the penis and erectile dysfunction (ED) has been clearly established [7]. In addition, ED is common in subjects with metabolic conditions, such as obesity, diabetes, hyperlipidemia, hypertension, and metabolic syndrome [7], and represents an established powerful predictor of overt and occult cardiovascular disease (CVDs) both in the general population [7, 8] and in populations at high cardiovascular risk, in particular in diabetic patients [9–12].

To better define the role of the arterial blood flow of clitoris in the development of FSD and to evaluate its possible association with the metabolic and cardiovascular risk some methods have been used. Among them, clitoral color Doppler ultrasound (CDU) has been proposed as a noninvasive and inexpensive method to assess clitoral vascular resistance by estimating the so-called pulsatility index (PI) [13]. An increased PI reflects an elevated resistance to blood flow and therefore suggests lesions of the vascular bed of the clitoris. Interestingly, some studies documented that PI is affected by smoking, alcohol intake, and all the features of the metabolic syndrome [14–16].

Transcutaneous oxygen tension ($TcPO_2$) represents an objective, noninvasive, and precise method to measure transcutaneous oxygen partial pressure, namely pO_2 at the skin surface. Therefore, it can document the tissue perfusion in several districts of the body [17]. In diabetic patients it is used as a noninvasive, non-operator-dependent, and inexpensive tool to assess vascular diabetic foot and peripheral artery disease (PAD) [18–20]. Some studies have shown that it may be even more reliable than other recognized diagnostic procedures, such as ankle–brachial index and toe blood pressure [19, 20].

On this basis, we hypothesize that the exact measurement of pO_2, namely of the oxygen partial pressure, at the mucosal surface of clitoris may represent an objective and reliable way to better evaluate tissue perfusion and the real condition of the vascular bed of clitoris. The oxygen partial pressure at the mucosal surface of clitoris may be called transmucosal oxygen tension ($TmPO_2$). This parameter may be used to deeply investigate the relationship between tissue perfusion of clitoris and FSD. In addition, $TmPO_2$ may be tested as a marker for the cardiometabolic risk of women.

The aim of this study was to evaluate whether $TmPO_2$ can be measured at the mucosal surface of clitoris and whether the measurements are reliable.

Methods

Six volunteer, fertile, healthy, and sexually active nurses of the Clinical Institute Beato Matteo of Vigevano, Italy were recruited. They gave their informed consent to participate in the study. They were heterosexual women, married or in a stable relationship (>12 months). The exclusion criteria were as follows: any chronic disease and/or any recent acute disease occurred within previous 6 months, any chronic or recent treatment (previous 6 months) with any type of medications or nutraceuticals, recent sexual intercourse (<48 h), and BMI >24.9. The procedure was exploited during the early follicular phase (days 3–5). No specific questionnaire was administered to exclude FSD. To measure $TmPO_2$ of the clitoris a TCM CombiM Radiometer (Medical Aps, Bronshoj, Denmark) device was used. The smallest sensor and its fixation ring, usually used in newborns, was adopted for the measurements. All details of the procedure are described in the operator's manual of the supplier. However, the procedures were identical to those used to detect $TcPO_2$ at the skin surface of the foot [1].

After the calibration of the sensor at atmospheric air (air room), the fixation ring of the sensor is applied to the measuring site by pressing the center of the fixation ring onto the measuring site with a finger and then running a finger around the ring circumference. The hole of the fixation ring is filled in with three to five drops of the contact liquid.

The sensor is removed from the calibration chamber, the arrow of the sensor is aligned with one of the marks of the fixation ring, and the sensor is turned a quarter of a turn clockwise to fasten it in the fixation ring.

On the monitor of the device it is possible to view the trend curve of $TmPO_2$. When the sensor is applied, PO_2 corresponds to that of the atmospheric air; then, PO_2 declines in a few minutes (stabilization time) and reaches a stable $TmPO_2$ reading (plateau phase). Stable $TmPO_2$ continues for about 15 min and then PO_2 value suddenly increases and comes back to the value of the atmospheric air. The stable $TmPO_2$ during the plateau phase corresponds to $TmPO_2$ of the clitoris. When PO_2 comes back to that of atmospheric air, the sensor is removed from the measuring site. All measuring data are exported to the PC. The device gives a measurement every 20 s. $TmPO_2$ of the subject is defined as the mean of all measuring data during the plateau phase, namely from the end of the stabilization time to the moment of the sudden increase of PO_2 towards that of the atmospheric air.

Statistical analysis

This study reports only descriptive statistics. No comparison was exploited.

Table 1 Demographic data and $TmPO_2$ of the clitoris of six healthy women

Subject number	Age (years)	BMI	Current smoker	Previous pregnancies	Oral contraceptive use (more than 6 months ago)	$TmPO_2$ (mmHg)
1	33	22.7	No	Yes	Yes	42.8
2	27	21.8	No	Yes	Yes	41.0
3	34	23.7	No	Yes	Yes	49.1
4	25	19.4	No	Yes	No	53.4
5	31	22.1	Yes	No	No	37.5
6	31	24.3	No	Yes	Yes	24.1

$TmPO_2$ transmucosal oxygen pressures

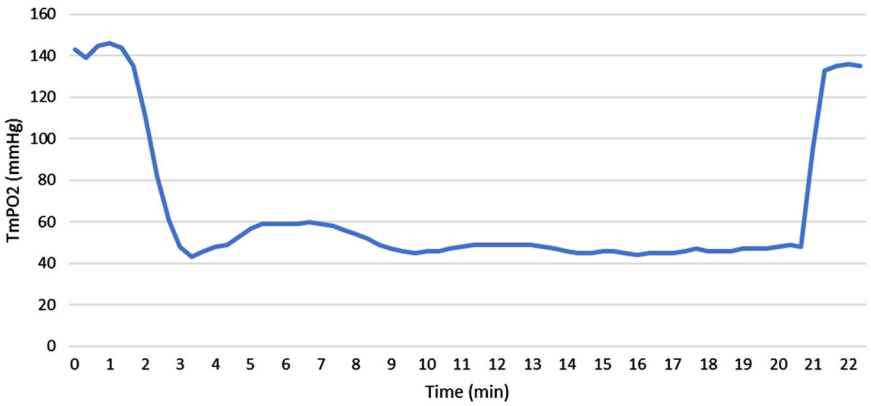

Fig. 1 Trend curve of $TmPO_2$ (transmucosal oxygen tension) of the clitoris in one woman

Results

Demographic data and $TmPO_2$ of six women are depicted in Table 1.

The mean value of $TmPO_2$ is 42.3 mmHg. As shown, five out of six women had a $TmPO_2$ between 37.5 and 53.4 mmHg. Only one woman had a low $TmPO_2$ (24.1 mmHg) when compared to the rest of the subjects. However, in all the women, including the one with a low $TmPO_2$, the trend curves showed identical behavior. In all the subjects we observed a short stabilization time (duration of about 3–5 min), a plateau phase with a stable $TmPO_2$ (duration: from 12 to 18 min) that suddenly finishes with a gradual come back to the PO_2 recorded at the beginning of the procedure. Interestingly, the curve trends of $TmPO_2$ are identical to the trend curves of $TcPO_2$ recorded on the skin of the foot [19].

Figure 1 shows the curve trend of one of the six women.

During all the procedures, no problem occurred. In particular, among the potential risks described in the operator's manual of the supplier (risks of burn, skin or mucous damage, bruise, incorrect measurement, and fire), none of them occurred.

To avoid the risk of incorrect measurements, sensor temperature and PCO_2 were monitored during all the procedures. The sensor temperature was between 43 to 44 °C, as recommended by the supplier. In addition, a stable PCO_2 during the stable $TmPO_2$ phase was used as an indirect sign so that the oxygen partial pressure was not affected by the atmospheric air. Indeed, PCO_2 is very low during the stabilization time and gradually increases; then, it has a stable phase which ends with a decrease of its partial pressure. In other words, $TmPO_2$ and $TmPCO_2$ typically have a specular trend curve.

Discussion

Abnormalities in the arterial blood flow of the genital tissues are associated with changes in female sexuality [1, 2] and may be linked to higher risk for metabolic and CVDs in women [3–6]. Several methods have been proposed to document alterations in hemodynamics of clitoris and vagina. Among these methods CDU certainly represents a reliable tool, as it measures PI that reflects resistance to blood flow [13].

As documented in the diagnosis of PAD, especially in diabetic patients, $TcPO_2$ may be a more effective, objective, and reliable method to measure tissue perfusion than ABI and toe blood pressure [19, 20]. In addition, unlike echo color Doppler, it is not operator-dependent.

Therefore, we decided to evaluate if oxygen partial pressure can be easily measured at the mucosal surface of the clitoris. We used the same method for the assessment of $TcPO_2$ at the skin surface of the foot. Considering that clitoris is covered by mucosa and that the measuring site is

quite small, we have chosen the smallest sensor, usually used in newborns. We cannot exclude that specific sensors for mucosa may be developed in the future, but there was no problem with sensors for newborns during the measurements. In addition, all the measurements appear to be reliable, as the trend curves were very similar to those recorded on the skin of the foot [19].

The aim of the present study was only the validation of the method in a new measuring site. Therefore, we are not able to give an exact range of normality of $TmPO_2$ of clitoris in healthy women. Five out of six women had a $TmPO_2$ in the range 35–55 mmHg, which may theoretically represent a range of normality. On the contrary, one subject had a low $TmPO_2$, far from this range. In any case, we noted that the curve trend of $TmPO_2$ in a woman with a low value was similar to those of other women. This suggests that the measurement was correct. On the other hand, in this woman the measurement was repeated the day after and similar data were found. Therefore, the biological and clinical meaning of this finding remains unclear. We cannot exclude the presence of FSD, as specific questionnaires were not administered.

Sexual/clitoral stimulation may also affect the results. Therefore, we included recent sexual intercourse among exclusion criteria. However, specific work is needed to clarify the potential impact of sexual/clitoral stimulation on $TmPO_2$.

If other work confirms the reliability of $TmPO_2$ as non-invasive, non-operator-dependent, and inexpensive tool to accurately measure the oxygen partial pressure of clitoris and accordingly to precisely define the status of the arterial blood flow, perspectives could be of great interest. First of all, specific studies may better evaluate the exact role that tissue perfusion and hemodynamics of clitoris can have on female sexuality. In addition, other work can clarify whether $TmPO_2$ can be used as a powerful predictor for metabolic and CVDs in women. Indeed, in men ED is an established cardiovascular risk factor [7–12], but in women there are no specific markers to evaluate if FSD can be associated with a greater cardiovascular risk. This may be due to the fact that FSD is a very complex condition due to many factors and characterized by many potential disorders [1]. Therefore, validated questionnaires to assess FSD may have a low predictive power when tested as potential predictors of cardiovascular events. $TmPO_2$ is linked only to tissue perfusion of clitoris and therefore may become a reliable marker of cardiovascular risk associated to female sexual health. This may permit both to better discriminate the individual cardiovascular risk of the woman and to find occult CVD, especially in diabetic women on the basis of specific screening programs [21, 22] that may improve the prognosis [23].

In conclusion, $TmPO_2$ can be easily measured at the mucosal surface of clitoris. Large epidemiological studies in healthy and unhealthy women and in women with FSD are needed to establish both the normal range of $TmPO_2$ and the meaning that different values of $TmPO_2$ can have on sexual and general health of the women.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The informed consent was obtained from all the subjects recruited in the study.

Informed consent Informed consent was obtained by all the subjects recruited in the study.

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