Peripheral blood saturation and pulse rate during swallowing in patients with oral cavity neoplasm and after its excision

Nasycenie krwi obwodowej tlenem i tętno podczas przełykania u pacjentów z nowotworem jamy ustnej oraz po jego wycięciu

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Abstract

Background. Breath holding during swallowing enables safe transport of bolus from the oral cavity to the esophagus without threat of aspiration into the lower airways. Inter-deglutition apnea elongation needed for the performance of several swallows supporting non-efficient lower pharynx emptying in the patients after oral cavity neoplasm excision, may be the cause of the peripheral blood saturation decrease.

Objectives. The aim of the study was to assess peripheral blood saturation during swallowing in patients with oral cavity neoplasm and after its excision.

Material and methods. One hundred fifty-six patients with oral cavity neoplasm were scheduled for surgical treatment. Pulse oximetry was performed before surgery, and 2 and 4 weeks post-surgically. Video fluoroscopic swallowing examination was performed 2 and 4 weeks post-surgically, simultaneously with pulse oximetry.

Results. After neoplasm excision, desaturation was indicated by time percentage of saturation lower than 95% increase and pulse rate acceleration. We recorded improved saturation 4 weeks after surgery and after the rehabilitation of swallowing; there was an increase in the lowest saturation value and a decrease in time percentage of saturation lower than 95%. Post-deglutition retention correlated most with the saturation. Time percentage of saturation lower than 95% for post-deglutition retention was a sensitive test in 82%, and a specific test in 70%.

Conclusions. The course of act swallowing improves in patients subjected to swallowing rehabilitation after oral cavity neoplasm excision as time passes by after surgery. Desaturation during swallowing in patients after oral cavity excision improves as time passes by in patients subjected to swallowing rehabilitation. Post-deglutition retention indicating that inefficient swallowing and aspiration threat are present is a feature of disturbed swallowing act which correlates the most with desaturation, especially with time percentage of saturation lower than 95%.

Key words: deglutition disorders, saturation, oral cancer excision, post-deglutition retention

Słowa kluczowe: zaburzenia połykania, nasycenie tlenem, wycięcie raka jamy ustnej, zaleganie popołykniciowe

Breathing, one of the most important life functions, may be temporarily restricted during phonation and swallowing. In proper deglutition the larynx closure lasts from 0.4 to 0.6 s and generally does not lead to desaturation¹, except for in older patients.^{2–5}

Oral neoplasm excision changes the anatomy and functions of organs responsible for swallowing, speech creation and breathing. A decrease in the organ mass, movement limitation and limited sensory efficiency disturb swallowing by preventing patients from feeding themselves orally. Reconstruction of excised structures, even if performed in one-step surgical procedure, does not guarantee the recovery of efficient swallowing and eligible speech⁶. Teaching patients saliva swallowing, especially long breath-holding, creates a new pattern of swallowing. Such an elongated, mid-swallowing apnea can lead to reduced peripheral blood saturation. The level of desaturation and its duration may indicate the necessity of some changes in planned swallowing reeducation.

The aim of this study was to assess saturation as one of the significant conditions in swallowing rehabilitation after oral cavity neoplasm excision.

Material and methods

One hundred fifty-six patients were treated surgically due to oral cavity neoplasm: 110 men aged 22–86 years (mean age 56.7), and 46 women aged 37–77 years (mean age 57.35). The criterion of inclusion into the study group was histopathologically diagnosed primary squamous cell carcinoma of its origins in oral cavity mucosa. Patients with cancer recurrence or with respiratory, heart or blood vessels diseases were not included into the study group. The patients were not diagnosed nor treated due to breathing or swallowing disturbances before surgery. Neoplasm, the range of excision, and reconstruction data are presented in Table 1.

Pulse oximetry of the peripheral blood saturation was performed in patients with oral cavity cancer before surgery, and 2 and 4 weeks post-surgically. All patients were advised to learn how to swallow their saliva freely; in the early post-surgical period they were asked for planned saliva swallowing every hour. Two weeks after surgery, patients considered their saliva swallowing as effortless.

Before surgery, saturation assessment was performed in the early hours, between 9 and 10 a.m. For the first 15 min, peripheral blood saturation was examined in patients during their usual daily activities; a further part of examination was performed as the patient drank 25 mL of still mineral water; another 15 min of the examination was performed during patients' usual daily activities. Two and 4 weeks after surgery, saturation assessment began 15 min before video fluoroscopic swallowing examination, continued during the examination, and finished 15 min after video fluoroscopic swallowing examination.

The index finger of a patient's right hand was placed in the pulse oximeter sensor. The measurement was performed with the use of Pulse Oximeter Palmsat® 2500 (Plymouth, USA) and based on the assessment of the red and sub-red light absorbance by the red blood cells flowing through a blood vessel. The result was diversified accordingly with oxyhemoglobin content in the red blood cell. The changes in the light absorbance produced by the blood pulse in a blood vessel were used to assess the pulse rate. The recording of examination was stored in the Pulse Oximeter device memory, and then entered into a database created by the manufacturer. The database was able to gather any number of examination results. We chose 5 scores from the gathered data: basal saturation, minimum saturation, the average number of pulse rate per min, the minimum number of pulse rate per min, and the percentage of time period with saturation lower than 95%.

Saturation and pulse rate were examined before surgery in 75 patients, 2 weeks post-surgically in 133 patients, and 4 weeks post-surgically in 66 patients. Saturation assessment in the group of 156 patients was possible due to the following reasons: 1) only 75 patients spent the night before surgery in the hospital; 2) 23 patients with oral nutrition left hospital no later than 2 weeks after surgery; 3) 90 patients decided for oral nutrition no later than 4 weeks after surgery.

Two weeks after surgery, 133 patients fed with nasogastric tube who did not start oral feeding, were subjected to the swallowing rehabilitation. It was preceded by video fluoroscopic examination performed as in Dodds, Logeman and Steward's research.^{7,8} The examination showed aspiration, leakage into the larynx vestibule, post-deglutition retention in the lower pharynx, and oral cavity outflow apart from jaws occlusion. The examination verified the compensatory mechanisms applied spontaneously by patients during swallowing, enabled checking the effectiveness of new maneuvers recommended during the examination such as changing the posture, apnea elongation, epiglottal and supra-epiglottal swallowing. Each patient was provided with their swallowing recording with the information on the causes of swallowing disturbances and rehabilitation recommendations. Peripheral blood saturation assessment performed during video fluoroscopic swallowing examination facilitated the observation and recording of saturation of which parameters were changing during swallowing.

Four weeks after surgery, 66 patients still fed through nasogastric tube were subjected to video fluoroscopic examination of swallowing. The examination enabled us to check the effectiveness of previous swallowing rehabilitation and possible changes which could be applied in the further course of rehabilitation. The changes were discussed with every patient during watching the recorded swallowing act. The assessment of saturation completed the observation made during the examination 3.

Table 1. Characteristic of squamous oral cavity cancer; treatment

Tumor localization, clinical advancement, treatment		Number of patients		
Tumor localization	tongue		48	
	tongue root		16	
	floor of the mouth		42	
	mandible, lower gingiva		21	
	retromolar trigone		19	
	others		10	
Clinical advancement	I		32	
	II		40	
	III		58	
	IV		26	
Treatment	surgical (only)		28	
	surgical + radiotherapy		44	
	surgical + radiotherapy + chemotherapy		84	
The range of oral cavity tissues excision		reconstruction	yes	no
	1) front of part of tongue, floor of mouth, mandible	23	14	9
	2) lateral part of tongue, floor of mouth, mandible	58	24	34
	3) a half of mandible and half of tongue along	7	5	2
	4) together as in 1 and 3 group	2	2	0
	5) whole tongue	4	4	0
	6) a half of the tongue along	11	4	7
	7) ramus of mandible, lateral pharynx part, root of tongue	51	16	35

Statistical methods

Pulse oximeter recordings were gathered in a database, and after compiling them with the parameters of features of the disturbed swallowing act, analyzed with the use of:

- Student's *t*-test of the dependent variables or the Wilcoxon test of 2 related samples from the same patient in 2 examinations.

- Analysis of variance (ANOVA) or Kruskal-Wallis test.
- Student's *t*-test for independent variables or the Mann-Whitney *U* test.
- The Kolmogorov-Smirnov test.
- Spearman's rank correlation test.

The results were described with the use of the correlation coefficient *r* and *p* value. *P* < 0.05 was considered as statistically significant in all of the aforementioned tests.

Results

Pulse oximetry assessment

In the study group of 156 patients, there were no statistically significant correlations between peripheral blood saturation and the patient's age or gender. However, we

reported statistically significant differences (*p* = 0.0001) in the rate of the slowest pulse. In post-surgical examinations, the rate was on average 10 beats per min higher in women than in men.

During examination 1, before the surgery performed on 73 patients, we reported that the neoplasm localization in the front part of the oral cavity was statistically significantly correlated (*p* = 0.0053) with the lowest peripheral blood saturation during swallowing. Neoplasm infiltrating the tongue was statistically significantly correlated (*p* = 0.0315) with longer lasting time of peripheral blood saturation lower than 95% during swallowing compared to patients with other localizations of the neoplasm. Table 2 presents the medium values of saturation and pulse rate measurements from examinations performed in patients with oral cavity neoplasm, and after 2 and 4 weeks post-surgically.

In examination 2, performed on 133 patients 2 weeks after surgery, we reported the percentage elongation of saturation time lower than 95% (*p* = 0.0374), as well as a statistically significant increase in the pulse rate (*p* = 0.0075) in comparison with the pre-surgical examination recorded. Moreover, we observed a minor and statistically insignificant decrease in basal and minimum saturation.

In the examination 3, performed on 66 patients 4 weeks after surgery, we reported a statistically significant improvement in measurements concerning the saturation in comparison with the examination 1; the lowest saturation increased (*p* = 0.0027), and the percentage of saturation time was lower than 95% decrease (*p* = 0.0047).

Video fluoroscopic examination

In the examination conducted 2 weeks after surgery we reported a disturbance of bolus formation in the oral cavity, inefficient oral bolus transport, premature bolus entry in the pharynx, post-deglutition retention in the oral cavity and pharynx, ineffective lower airways closure during swallowing, leakage into the laryngeal vestibule, and aspiration. Table 3 presents the chosen features of disturbed act of swallowing recorded in patients after 2 and 4 weeks following oral cavity neoplasm excision. The number of patients with disturbances in examination 3 was lower in comparison to examination 2.

The most serious swallowing disturbance, aspiration, did not correlate in a statistically significant manner with the age or gender of patients. Aspiration correlated statistically significantly with the range of tumor excision, i.e., it was recorded more often after the excision of more than a half of the movable part of the tongue (*p* = 0.00585) – group 4, and after the excision of the root of the tongue (*p* = 0.00785) – group 7. Aspiration correlated with post-deglutition retention in the lower larynx (*p* = 0.00001). The number of patients with aspiration decreased from 10 to 7 during a 4-week observation.

Table 2. Chosen values of saturation measured during swallowing in patients after oral cavity neoplasm excision

Variable	Examination	Compared	p	Mean 1	Mean 2	N1	N2
Basal O ₂	1	2	0.1187	96.21	95.74	73	133
	1	3	0.1719	96.21	95.77	73	66
	2	3	0.9140	95.74	95.77	133	66
min. O ₂	1	2	0.0562	90.22	88.00	73	133
	1	3	0.3616	90.22	91.11	73	66
	2	3	0.0083	88.00	91.11	133	66
avg. p.r. (bpm)	1	2	0.0075	80.98	86.41	73	133
	1	3	0.0007	80.98	89.50	73	66
	2	3	0.1646	86.41	89.50	133	66
low p.r. (bpm)	1	2	0.6247	60.36	61.33	73	133
	1	3	0.0775	60.36	64.53	73	66
	2	3	0.1512	61.33	64.53	133	66
% of swallowing time when saturation < 95%	1	2	0.0374	17.21	26.43	73	133
	1	3	0.7804	17.21	16.09	73	66
	2	3	0.0215	26.43	16.09	133	66

Examination 1 – before surgery, examination 2–2 weeks post-surgically, examination 3–4 weeks post-surgically; basal O₂ – basal peripheral blood saturation; min. O₂ – minimal peripheral blood saturation; avg. p.r. – average number of pulse beats per min; low. p.r. – lowest number of pulse beats per min; % of time O₂ < 95% – time percentage when saturation is lower than 95%; N – number of patients in study group; p – level of statistic significance of differences

Table 3. Chosen swallowing disturbances in patients after oral cavity neoplasm excision diagnosed in a video fluoroscopic examination

Features of disturbed swallowing act	Examination 2: 2 weeks post-surgically	Examination 3: 4 weeks post-surgically
Oral cavity outflow	15*–11%	11–17%
Post-deglutition retention	38–28%	28–43%
Leakage into laryngeal vestibule	26–20%	12–18%
Aspiration	10–8%	7–11%
Number of patients	133	66

* the number of patients representing a feature.

Disturbed swallowing features vs saturation

In examination 3, oral cavity outflow, post-deglutition retention in the lower pharynx, leakage into the laryngeal vestibule and aspiration were present in fewer patients, but the frequency of disturbances (except the leakage into the laryngeal vestibule) was higher. The aforementioned features of the disturbed swallowing act were juxtaposed with the measurements of its saturation (Table 4). Post-deglutition retention was accompanied with statistically significant saturation in terms of basal saturation, minimal saturation, and lasting time percentage of peripheral blood saturation which was lower than 95%. Outflow from the oral cavity and leakage into the laryngeal vestibule were accompanied by statistically significant per-

centage of lasting time of peripheral blood saturation lower than 95%.

Time percentage of saturation lower than 95% was the most differentiating value of peripheral blood saturation during swallowing in patients with outflow from the oral cavity, leakage into the laryngeal vestibule, and post-deglutition retention, from the patients in whom the aforementioned disturbances were not present.

Nutrition of patients' choice or recommended by the doctors

Before 2 weeks passed after the surgery, 23 patients were able to start oral nutrition with a liquid diet. These patients belonged to group 2 due to the range of surgery (their tumor was excised along with the lateral part of the tongue, floor of mouth, and a segment of mandible of full thickness); in all of these cases the continuity of mandibular arch was reconstructed in one stage with neoplasm excision.

Two weeks after surgery and a video fluoroscopic examination, 67 patients started oral nutrition, and 66 of the patients were further subjected to the nasogastric tube feeding and then swallowing rehabilitation was applied to them. Four weeks after surgery and video fluoroscopic examination, another 39 of the patients started oral nutrition. Feeding through the nasogastric tube or temporary gastrostomy with further swallowing rehabilitation were suggested in 27 of the patients.

Saturation values of patients who were able to return to oral nutrition were compared with the adequate values of

Table 4. Disturbed features of swallowing act vs. chosen values of saturation in examination performed 4 weeks post-surgically

Disturbed swallowing features	The number of patients	Chosen values of saturation					
		basal O ₂	p	min. O ₂	p	% of time with sat. < 95%	p
Outflow	yes 11	95.02	0.1002	89.64	0.1172	32.48	0.0029
	no 55	95.92		91.44		12.75	
Retention	yes 28	94.49	0.0000	88.46	0.0000	33.30	0.0000
	no 38	96.72		93.07		13.06	
Leakage	yes 12	95.15	0.1878	90.09	0.3367	27.45	0.0072
	no 54	95.90		91.32		13.77	
Aspiration	yes 7	95.75	0.5493	91.10	0.9101	11.50	0.8792
	no 59	96.60		91.50		16.23	

p – the level of statistically significant differences.

patients who needed nutrition through nasogastric tube or gastrostomy. Saturation time lower than 95% was reported in patients who, according to a video fluoroscopic examination of swallowing assessment, were able to return to oral nutrition, and a higher percentage of lasting time of peripheral blood saturation which was lower than 95%, was reported in patients who needed to be fed through a nasogastric tube or gastrostomy. The difference was clear in examination 2 and highly statistically significant in examination 3. Table 5 includes the comparison of time percentage of saturation lower than 95% during swallowing in particular examinations and suggested way of nutrition on the basis of video fluoroscopic examination complemented by pulse oximetry.

We complied the range of surgery, time percentage of saturation lower than 95% in examination 3, and the recommended method of nutrition. Minimum differences between the compared time percentages of saturation lower than 95% in patients with maintained nasogastric tube and patients who were able to start oral nutrition amounted to 6.1% in the group 3 (after resection of half of mandible and the tongue); the greatest differences of 30.35% were recorded in the group 7 (after the resection of mandibular ramus, lateral wall of pharynx and a part of root of the tongue). Statistically significant differences of the compared values concerned group 2 (the excised lat-

eral part of the tongue, floor of the mouth, and mandible), where the level of statistical significance was $p = 0.0015$, and group 7 (excised ramus of mandible, lateral part of the pharynx, and a part of root of the tongue), where the level of statistical significance was $p = 0.0002$. Fig. 1 shows the comparison of percentage of lasting time of saturation to be lower than 95% in patients who were fed naturally and in patients with a maintained nasogastric tube, considering the range of surgery; groups 3, 4 and 5 (the range of surgery concerned more than a half of the tongue) were joined into one group to facilitate the compilation.

Additionally, we performed a comparison of distribution of dependent variables with the Kolmogorov-Smirnov test for outflow, retention and leakage. ROC curves analysis was performed for the variables which in the Kolmogorov-Smirnov test were significant to achieve the cut-off point which differentiates the distributions the best. The best cut-off ($\geq 12.2\%$) was chosen for the maximum value of the defined difference on the basis of ROC curves; sensitivity array was 82%, and specificity array was 70%. For the percentage of lasting time of measurements equal or higher than 12.2%, sensitivity array of retention was 82%, i.e. in 82% of patients with retention lasting time of saturation lower than 95% was equal or greater than 12.2%, and only 30% of patients without retention showed such time.

Table 5. Time percentage of saturation lower than 95% during swallowing vs. recommended way of nutrition in patients after oral cavity neoplasm excision

Examination	The way of nutrition	The number of patients	Mean time percentage of saturation < 95%	Statistical significance of differences
1	oral	73	16.84	0.0836*
2	planned oral	87 (out of 133)	22.78	
	feeding tube maintained	46 (out of 133)	33.24	0.0000
3	planned oral	39 (out of 66)	11.97	
	feeding tube maintained	27 (out of 66)	26.12	

* in comparison to the results of patients who took part in both examinations.

Fig. 1. The necessity for nasogastric tube feeding and the possibility of oral nutrition vs time percentage of saturation lower than 95% in patients after oral cavity neoplasm excision concerning the range of tissues excision

Discussion

The role of pulse oximetry in diagnostics of swallowing disturbances is highly valued, especially in bedridden patients.^{9–11} A decrease in the peripheral blood saturation during swallowing, known as the aspiration index, is not only highly appreciated in diagnosing and treating swallowing disturbances, but also significant in aspiration diagnosis.^{10,12,13} The significance of desaturation in aspiration recognition in patients with swallowing disturbances after cerebrovascular accidents and nasopharyngeal cancer post-radiation was assessed by Wang, after performing statistical analysis which did not show to be a test of high sensitivity (58.3%), nor specificity (66.7%).¹⁴ However, Collins et al. reported that a decrease in saturation stands for a sensitive array for aspiration in patients after a stroke, therefore, the decrease in saturation was present in 81% of the patients with aspiration.¹⁵ The authors emphasize the need for careful interpretation of pulse oximetry results in elderly patients, smokers, or patients affected by chronic lung diseases.

Lack of time synchronization between the activities of oral and pharyngeal swallowing phase, which is present after oral cavity neoplasm excision, is one of the causes of swallowing disturbances. Long-lasting apnea, which begins long before the swallowing trial and lasts even several seconds, is an aspiration that prevents auto-regulatory mechanism applied by the majority of patients. It is accompanied by desaturation, which may be assumed to be an aspiration sensitive array (especially important in cases of 'silent aspiration'), and it is present in the patients who expect to aspirate.^{7,12,16,17}

In our study group of patients after oral cavity neoplasm excision, aspiration was not accompanied by the lowest value of peripheral blood saturation during swallowing. The measurements show post-surgical time-dependent variability of the peripheral blood saturation in the patients with oral cavity neoplasm, a significant decrease in

the saturation after neoplasm excision, and improvement after 2 weeks of swallowing rehabilitation. The value which changed the least was basal peripheral blood saturation; its fluctuations were less than 3%. The value which changed more (increasing) was the pulse rate; differences between the mean pulse rate in examination 1 and 2 was almost 6 beats per minute, and between examination 2 and 3 it was more than 3 beats per minute. The differences between the mean peripheral blood saturation which was decreased, in examination 1 and 2 during swallowing exceeded 2%, and in examination 2 and 3 they exceeded 1%. The mean percentage of lasting time of saturation lower than 95% decreased of more than 10% during swallowing rehabilitation, and it was increased of 9% after the surgery.

Higher values of minimal saturation, lower percentage of lasting time of saturation lower than 95%, and accompanying pulse rate acceleration were recorded in the examination 4 weeks post-surgically. Certainly, the saturation increase is associated with an improvement of a patient's general condition, but also with putting their swallowing act in order of its course. Video fluoroscopic examination of swallowing plays a key role in enabling the physician and the patient to assess the threat of aspiration, the best position to lower the aspiration risk, and the time of essential mid-swallowing apnea. Providing the patient with a recording of their swallowing act course enables us to determine the moment of apnea and first after-swallow breathe-in with the patient. Deliberate and conscious breathing prevention during swallowing, which lasts long enough to push the bolus into the esophagus but no longer than it is needed, shortened the time of peripheral blood saturation lower than 95%.

Reports on the unfavorable influence of the activities which improve the inefficient swallowing on the circulatory system (e.g. elongated apnea) called for some additional caution as far as their application in the elderly patients and in patients with heart and vessels diseases is considered.^{1,4,16,17} The possibility of saliva aspiration as

well as ‘silent saliva aspiration’ reported by Takahashi in the elderly patients discourages from creating a situation in which a patient makes decision on how to swallow on his/her own, especially when there may be other diseases co-existing with the oral cavity neoplasm which may complicate swallowing rehabilitation if the rehabilitation is not monitored.¹⁸ The results of Colodny’s research show different general diseases as the cause of desaturation, and negate the advanced age importance in low peripheral blood saturation.^{1,12} Morton et al. finding, based on their research performed in patients with neurologically conditioned oral phase disturbances, that there is a need for research on the influence of breathing control improvement on aspiration reduction in the patients makes the relationship between saturation and oral nutrition possibility worth considering.¹⁹

Despite the fact that our patients were not diagnosed nor treated due to any cardiovascular system disease, the need for determination of saturation and pulse rate changing during swallowing is justified. Saturation decrease of 62%, pulse rate acceleration to 128 beats per minute, and saturation lower than 95% and lasting for over 50% of examination time recorded during swallowing are the unfavorable conditions for oral nutrition. The aforementioned conditions support the idea of changing the current compensatory maneuvers which make the swallowing more efficient, as well as performing the video fluoroscopic examination of swallowing once again.

Pulse oximetry as a complementing method for the video fluoroscopic examination of swallowing in patients after oral cavity neoplasm excision yielded more information to the examination in our patients. Pulse oximetry showed decreased peripheral blood saturation and increased pulse rate in the examination performed 2 weeks post-surgically in comparison with the pre-surgical examination, and the lack of statistically significant correlation between the decrease in peripheral blood saturation and aspiration. The examination enabled us to emerge 3 features of disturbed swallowing in the examination performed 4 weeks post-surgically; post-deglutition retention, leakage into the laryngeal vestibule, and oral cavity outflow were accompanied by significant saturation decrease. The feature which had the greatest correlation with desaturation was post-deglutition retention accompanied by the highest percentage of lasting time of saturation lower than 95%.

Shortening the time of saturation lower than 95% during swallowing after oral cavity neoplasm excision was only possible thanks to achieving full understanding of the patients swallowing act recording, as well as teaching patients when to hold breath and perform the first breath-in after swallowing.

Systematic recording and an analysis of the swallowing acts disturbances in patients after excising the advanced oral cavity neoplasm and accompanying changes in peripheral blood saturation will facilitate monitoring of swallowing rehabilitation.

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