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REVIEW ARTICLE

Speech and swallowing after surgical treatment of advanced oral and oropharyngeal carcinoma: a systematic review of the literature

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Abstract Purpose of this review is the evaluation of speech and swallowing function after surgical treatment for advanced oral and oropharyngeal carcinoma. A systematic literature search (1993–2009), yielding 1,220 hits. The predefined criteria for inclusion in this systematic review were oral or oropharyngeal cancer, surgical treatment, speech and/or swallow function outcome, T-stage ≥ 2, patient cohort > 20, adequate description of the patient cohort in terms of tumor (sub) site, and low risk of bias (Cochrane criteria). Twelve studies fulfilled the predefined criteria. The results for speech more than 1 year after resection of oral or oropharyngeal cancer are reported to be moderate to good; although in the majority of patients speech is experienced as deviant. Overall sentence intelligibility scores are normal (92–98%). Swallowing is reported to be often already disturbed before treatment and is even more severely compromised after treatment. Aspiration rates of liquids vary from 12 to 50% and especially after oropharyngeal resection, pharyngeal transit times are delayed. Postoperative radiotherapy further increases function disturbances significantly. Critical subsites with regard to speech are the mobile tongue, and the soft palate and for swallowing, the floor of the mouth, the posterior base of tongue and the hard and soft palate. Prosthetic appliances (e.g., obturators, palatal augmentation prostheses) can diminish function losses considerably. Surgery for oral and oropharyngeal cancer yields function deficits, most notably with regard to swallowing. Series are small and outcome measurements vary. Therefore, to optimize pre-operative risk assessment, there is a need for internationally standardized outcome measurements.

Keywords Speech · Swallowing · Oral and oropharyngeal carcinoma · Surgery

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Introduction

During the last decade, functional consequences and quality of life after head and neck cancer treatment have become increasingly important outcome parameters. Despite all efforts to limit the functional sequels of the various treatments, post-treatment speech and swallowing problems continue to exist [1, 2]. Although there are obvious differences with regard to functional outcomes between the two main curative treatment modalities, surgery (with or without postoperative radiotherapy) and chemoradiation, the magnitude and extent of these differences remain controversial [3, 4].

Treatment choices depend on several factors, such as the site of the tumor, tumor stage, co-morbidity, and wishes and expectations of the patient. Also surgical and reconstructive tradition and experience, and availability of and experience with (chemo)radiotherapy protocols may influence treatment choices. Generally, first choice still is radical surgery with (on indication) adjuvant radiotherapy.

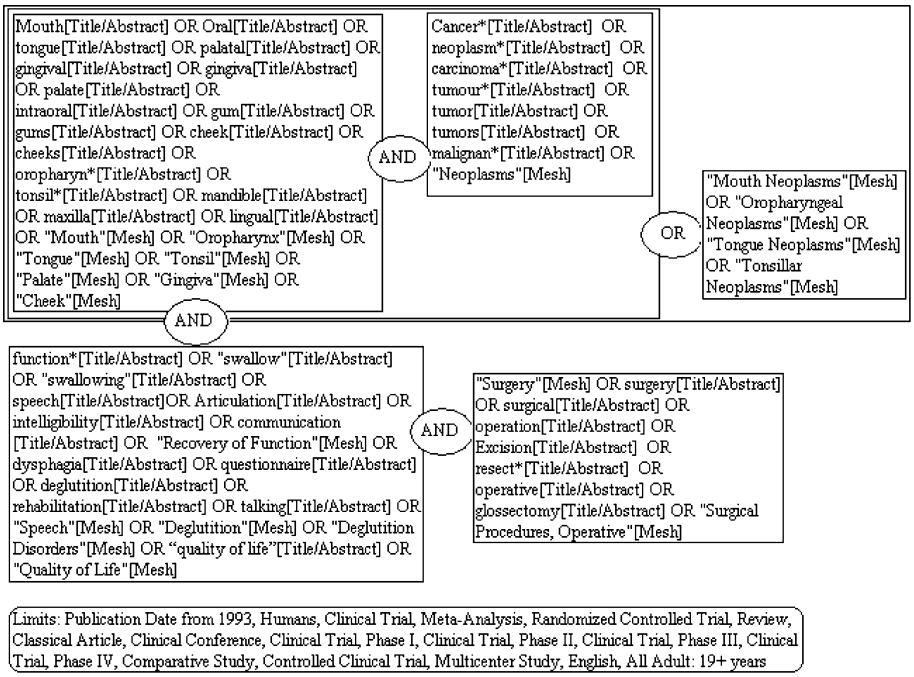

Fig. 1 Medline search for literature review to evaluate speech and swallowing after surgery for advanced oral and oropharyngeal cancer

If surgery is anatomically impossible or questionable, due to invasion of the skull base or carotid artery, patients currently often will be offered chemoradiotherapy. In addition, if surgery anatomically is still possible, but the expected function loss is judged to be unacceptable by both the surgeon and the patient, patients will be offered chemoradiotherapy. According to a recent survey in the Netherlands, primary surgery is considered to cause unacceptable function loss when tumor resection requires total glossectomy [5] and the term 'functional inoperability' is suggested for such a situation. Treatment advice is given by specialists, in an ideal setting after specialized tumor board discussion, but this is currently still mainly based on clinical experience, which is quite remarkable in this era of evidence-based medicine.

During the last two decades, a sizable number of studies have been published concerning the functional consequences of surgical treatment of advanced oral cavity and oropharyngeal cancer, with or without microvascular free flap repair [6]. In order to get a good overview of the present knowledge about the functional outcomes of such surgery, and to hopefully provide a more scientific basis for therapeutic/surgical decision-making in advanced oral cavity and oropharyngeal cancer, a systematic literature review was conducted.

Method

An extensive systematic literature search was performed in Medline, the Cochrane Library, Embase databases, and the National Cancer Database. All possible synonyms for oral and oropharyngeal carcinoma, surgical therapy, and function were entered to search in titles and abstracts, combined with index terms for the search in Embase and relevant MeSH terms in Medline, see Fig. 1 for medline search. Next to this, limits as English, publication date from 1993 on, adults (18+ years), humans, and relevant study designs were used.

Titles and abstracts of all hits were screened independently on relevance (matching patient group, treatment, outcome) by two reviewers, AK and LM, and articles that were considered possibly relevant were obtained full text and evaluated on relevance and risk of bias by the two reviewers independently. Relevance was scored A. absolutely relevant, B. rather relevant or C. not relevant, based on matching with the in- and ex-clusion criteria, see Table 1.

Inclusion criteria are:

- Patients with an oral or oropharyngeal carcinoma, at least 80% of the patient group or if results were described separately, at least 50%.
- A T-stage ≥ 2 in at least 80% of the patient group, or if results were described separately in at least 50%.
- Treatment that consists of primary surgery with or without adjuvant radiotherapy.
- Outcome measurements of speech and/or swallowing, objectively measured and/or subjectively assessed with a questionnaire.
- Tumor histology is squamous cell carcinoma.

Table 1 In- and ex-clusion criteria for relevance of article

For systematic review evaluating the functional results after surgery for oral and oropharyngeal cancer

Inclusion	Exclusion
• Oral cavity and/or oropharyngeal carcinoma > 80% or > 50% with the results discussed separately	• Inclusion of patients < 1,990
• T2–4 tumors > 80% or > 50% with the results discussed separately	• Population ≤ 20
• Treatment with surgery and if indicated adjuvant radiotherapy	• Treatment with chemoradiation
• Outcome measurements of speech and/or swallowing, objectively measured and/or subjectively assessed with a questionnaire.	• Lip carcinoma
• Squamous cell carcinoma	

Table 2 Criteria and definition of risk on bias, described by the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al. [7])

Criteria			Risk on bias	Interpretation	Relationship to criteria
Clear description of	Study group	Gender, age, histological diagnosis, T-stage and exact location of the lesion	A low	All criteria met	Plausible bias unlikely to seriously alter the results
	Followed treatment	Exact surgical intervention, method of reconstruction and % patients that underwent adjuvant radiotherapy	B moderate	One or more criteria partly met	Plausible bias that raises some doubt about the results
	Patient inclusion criteria	(No selection bias)	C high	One or more criteria not met	Plausible bias that seriously weakens confidence in the results
	Follow-up	Length, >3 months			
	% drop outs	Reason for dropout			
Reliability of outcome measurement	Referenced, validated or self made tests, observation of speech and swallowing by one or more observers, inter- and intrarater reliability percentage				

For systematic review evaluating the functional results after surgery for oral and oropharyngeal cancer

Exclusion criteria are:

- Patient inclusion before 1990.
- A population of less than 20 patients.
- Treatment with primary chemoradiation.
- Lipcarcinoma.

Risk of bias was scored A. low risk of bias, B. moderate risk of bias or C. high risk of bias, according to the Cochrane Handbook for Systematic Reviews of Interventions [7]. This evaluation was based on the criteria described in Table 2.

Results

The above described literature search, covering the period from the 1 January 1993 to the 1 February 2009, yielded 1,220 hits (Medline 592, the Cochrane Library 61, Embase 546 and the National Cancer Database 21). Of these, 207 studies were obtained full text (see Fig. 2). After careful evaluation, 12 papers were scored A–A or A–B for relevance and lack of bias and thus included, and 24 papers were considered second best, scoring B–A or B–B. The B–A/B articles were excluded, because more than 20% of the patient group had a T1 tumor, the description of the cohort or tumor localization was too confined, or the drop-out was more than 30% or without a clear explanation. As tumor localization and T-stage are very important factors for functional outcome, studies were not selected if they did not precisely describe their cohort with regard to these parameters. A complete table with exclusion reasons is available in the online version of the journal.

All studies meeting the predefined inclusion criteria were published during the last 8 years (2001–2008; see

Fig. 2 Literature search and article selection for evaluation of speech and swallowing after surgery for oral and oropharyngeal cancer. Original literature search yielded 1,220 hits, after screening of the title and abstract by two independent reviewers, 207 articles were selected and critically evaluated on relevance and risk of bias, leading to the selection of 12 articles to be included in this review. *A* first choice article, *B* second choice article

Table 3). The search from 1993 until 2001 did not result in any studies fulfilling the criteria. All included studies were cohort studies, and all cohorts included patients with primary squamous cell carcinomas of the oral cavity or oropharynx with a T-stage ≥ 2. The analyzed outcomes were quite variable and occurred in different combinations, i.e., nine studies used objective, and three subjective outcomes. In total, seven articles reported on intelligibility results; four studies reported on swallowing outcomes, assessed by means of videofluoroscopy or flexible laryngoscopy; three papers reported self-assessment of speech and swallowing outcomes by means of questionnaires. The results will be discussed per type of outcome and tumor site in the following section. For a summary of all objectively measured outcomes, see Fig. 3, showing a flowchart of all studies with objective outcomes of speech and swallowing, divided per tumor localization.

Speech

Intelligibility scores assessed by multiple blinded listeners with interjudge reliability scores are known to be a good parameter for speech function [8]. Three studies [9–11] evaluated intelligibility this way. Others [12–14] used multiple blinded listeners but gave no intra- and inter-rater reliability scores. Different tumor sites were evaluated. Four articles examined patients with tongue carcinoma [10, 12, 13, 15]. Other studies analyzed patients with oral and oropharyngeal cancer [9], only oropharyngeal tumors [14], or oral and oropharyngeal cancer with invasion of the soft palate [11].

Rieger et al. [10] followed 32 patients, who had a tongue carcinoma with at least 50% of the base of tongue resected without involvement outside the oropharynx. At 1 year postoperatively word intelligibility was 79%, sentence intelligibility 93%. Furia et al. [13] evaluated intelligibility of 27 patients who underwent a glossectomy. More than 6 months after a partial glossectomy or hemiglossectomy ($n = 12$) mean vowel intelligibility was 19 (scored on a 21-scale), after a subtotal glossectomy ($n = 9$) 17 (of 21) and after a total glossectomy ($n = 6$) 16 (of 21). Spontaneous speech was considered intelligible after a partial glossectomy or hemiglossectomy, partially intelligible after subtotal and intelligible 'with attention' after total glossectomy.

The cohort by Chien et al. [15] concerned 39 patients, who underwent total or nearly total glossectomy with laryngeal preservation. One year after surgery (without recurrence) only 3 of the 39 patients (8%) had unintelligible speech, the rest had intelligible speech. Unfortunately, the criteria for 'unintelligible speech' and the way of measurements are not clearly described in this article. Carvalho et al. [12] reported on spontaneous speech intelligibility, on average 32 months after hemiglossectomy or (sub)total glossectomy, for patients wearing a palatal augmentation prosthesis. Eight of 36 patients (22%) had normal spontaneous speech intelligibility, 11 of 36 (31%) had mild impairment, 9 of 36 (25%) moderate and 8 of 36 (22%) severe. With the prosthesis, intelligibility was significantly better than without. In addition, the syllable intelligibility improved with a prosthesis, and the formants, i.e., the natural resonance frequencies of the vocal tract, although they were still different, came closer to normal.

Borggreven et al. [9] described a prospective study of 80 patients with stage II–IV oral or oropharyngeal squamous cell carcinoma treated with microvascular soft tissue transfer. One year after surgery, intelligibility of a standardized text was assessed on a 10-point scale. The higher the score, the better the speech, with a score of 10 representing perfect speech and a score of ≤ 5 representing deviant speech. Mean score was (assessed from a box plot figure) approximately 4.2, and 71% of the cohort (30 out of 41 patients at 1 year) had deviant intelligibility, meaning a score below 6. In the same way, nasality and articulation were evaluated, resulting in 67% of patients having a deviant nasality score and 76% having a deviant articulation score.

In a retrospective cohort study of 55 patients who underwent resection of the soft palate as part of ablative cancer therapy, Bohle et al. [11] reported a median intelligibility of sentences of 94%. Patients who had tongue involvement had mean word intelligibility of 57%, and without tongue involvement 81%.

Rieger et al. [14] reported in oropharyngeal cancer patients at 1 year from surgery, a sentence intelligibility ranging from 92.4 to 98.7%, which was considered to be normal.

The results are difficult to compare in numbers due to different outcome measurements, but in general, the results for speech at 1 year after resection of oral or oropharyngeal

Table 3 Articles that met the inclusion criteria, describing functional results after resection of advanced oral and oropharyngeal carcinoma

	n =	Design	Patients treated by surgery and if indicated radiotherapy for:	Relevant outcomes	Results, >6 months after surgery	Comment and evaluation (relevance/risk on bias):
Bohle III [11]	55	R	Oral/oropharyngeal carcinoma with soft palate resection	Speech: Intelligibility Perceptual measures	Median sentence intelligibility 94%, Mean word intelligibility with tongue involvement: 52%, without: 81%	Histology and primary or recurrence not described A/B
Borggreven [9]	80	P	Stage II–IV oral or oropharyngeal carcinoma[a]	Speech: Intelligibility, articulation, nasality	71% of patients deviant intelligibility scores, 67% of patients deviant nasality, 76% deviant articulation	At 1 year only 42 patients available A/A
Borggreven [16]	80	P	Stage II–IV oral or oropharyngeal carcinoma[a]	Swallowing: videofluoroscopy, scintigraphy	25% of patients no aspiration, prolonged mean PTT, normal mean OTT	At 1 year only 32 patients available A/A
Carvalho-Teles [12]	36	R	Tongue carcinoma, with a palatal augmentation prosthesis	Speech: Intelligibility	22% of patients severe impairment of spontaneous speech intelligibility, the palatal prosthesis improved the intelligibility	T-stage not described, probably, outcome measurements not referenced A/B
Chien [15]	39	P	Tongue carcinoma, treated with larynx preservation	Speech/swallowing: Videofluoroscopy, intelligibility	8% of patients unintelligible speech, 25% aspiration of whom 10% significant	Outcome measurements and male/female ratio not described, A/B
Furia [13]	27	P	Tongue carcinoma	Speech: Intelligibility	After partial/hemi glossectomy intelligible speech, after subtotal partially intelligible, after total intelligible with attention.	No intra- or inter-rater reliability noted, primary or recurrence and follow-up not described, inclusion criteria not explicit, outcome measurements not referenced, A/B
Rieger [10]	32	P	Tongue carcinoma with $\geq$ 50% of the base of tongue resected, no involvement outside the oropharynx	Speech/swallowing: Intelligibility, videofluoroscopy	Word intelligibility 79%, sentence intelligibility 93%, 19% of patients had liquid aspiration, mean PTT/OTT prolonged	A/A
Rieger [14]	62	P	Oropharyngeal carcinoma, no oral invasion[a]	Speech: Intelligibility	Sentence intelligibility ranging from 92.1 to 98.4%	A/A
Rogers [20]	172	P	T3, T4 oral carcinoma	Speech/swallowing: UW-QoL	¾ of patients without RT have normal speech and swallowing, less then ½ of the patients with RT	Surgical intervention and exact tumor location not described A/B
Schoen [21]	50	P	Oral or oropharyngeal carcinoma (edentelous patients, treatment with implants)	Speech/swallowing: EORTC QLQ-C30, H&N35	Mean score of speech problems (0–100): RT/no RT, preop → postop; 9.9/6.9→ 20.8/9.0, swallowing 24.6/21.5 → 28.2/9.4	Follow-up and surgical intervention and reconstruction not clearly described A/B

Table 3 continued

	n =	Design	Patients treated by surgery and if indicated radiotherapy for:	Relevant outcomes	Results, >6 months after surgery	Comment and evaluation (relevance/risk on bias):
Tei [17]	25	P	Oral carcinoma[a], not upper jaw	Swallowing: barium swallow examination	12% of patients liquid aspiration, 88% of patients a dysfunctional swallowing efficiency	No T-stage (but AICC staging), histology and primary or recurrence described. A/B
Zuydam [19] 2005	278	P	Oral and oropharyngeal carcinoma	Speech/swallowing: UW-QoL	Mean score on speech item (0–100): RT/no RT, preop → postop, 95/96 → 70/77, swallowing; 88/88 → 63/86	Surgical intervention very limitedly described A/B

n number of patients; *P* prospective cohort study; *r* retrospective cohort study; *PTT* pharyngeal transit time; *OTT* oral transit time; *UW-QoL* University of Washington quality of life questionnaire; *EORTC QLQ-C30* the European Organization for Research an Treatment of Cancer Core Quality of Life Questionnaire version 30, *EORTC H&N35* the European Organization for Research and Treatment of Cancer Core Head and Neck Cancer Quality of Life Questionnaire

[a] Squamous cell carcinoma treated with microvascular soft tissue transfer

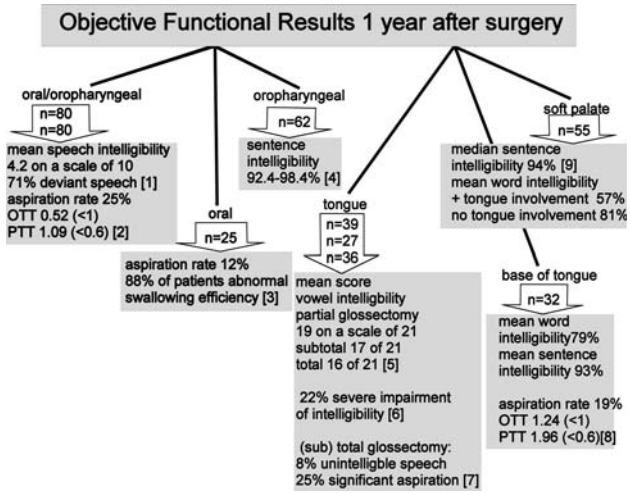

Fig. 3 Summary of results after extended literature search (1993–2009) for objective results of speech and swallowing after resection of advanced oral and oropharyngeal carcinoma. Nine studies are included, results are divided per tumor localization, as indicated by the subheading "oral", "oropharyngeal", etc. The numbers in the *arrows* represent the size of the patient group, if several numbers are shown it means that it contains results of multiple studies shown in the same order, see *references*. *OTT* oral transit time; *PTT* pharyngeal transit time; between *parenthesis* normal values are given. *1* Borggreven et al. [9], *2* Borggreven et al. [16], *3* Tei et al. [17], *4* Rieger et al. [14], *5* Furia et al. [13], *6* Carvalho et al. [12], *7* Chien et al. [15], *8* Rieger et al. [10], *9* Bohle III et al. [11]

cancer vary from moderate to good. Sentence intelligibility scores were considered normal (ranging from 92 to 98%) [10, 11, 14], word intelligibility was reduced (ranging from 51 to 81%) [10, 11]. In two cohorts, the majority (2/3–3/4) of patients postoperative spontaneous speech and standardized text intelligibility is regarded as "deviant"[9, 12], with high rates abnormal nasality and articulation evaluation [9] and abnormal formants, i.e., unnatural resonance frequencies [12].

Swallowing

Three studies analyzed swallowing function by videofluoroscopy at 1 year after surgery. Borggreven et al. [16] analyzed this in a cohort of 80 patients with oral and oropharyngeal cancer, Tei et al. [17] in 25 patients with oral carcinoma treated with free flaps, and Rieger et al. [10] in 32 patients with at least 50% of the base of tongue resected, without further involvement of the oropharynx.

Videofluoroscopy allows, among others, the assessment of the oral transit time (OTT) and pharyngeal transit time (PTT), which are frequently used as parameters of swallowing function, with normal scores for OTT < 1 s and for PTT < 0.6 s [18]. Borggreven et al. [16] reported a mean oral transit time (OTT) for liquids of 0.52 s and a pharyngeal transit time (PTT) of 1.09 s at 1 year after surgery. Rieger et al. [10] found a mean OTT for pudding of 1.24 s

and a mean PTT of 1.96 s. This means that in both cohorts, the PTT was prolonged, and was normal in only 53% of patients in Borggreven's study. In Rieger's study [10] also is found that the OTT was longer than normal at 1-year post surgery. In the study of Borggreven et al. [16], also the oral and pharyngeal phase were globally evaluated by experienced speech therapists and were judged to be abnormal in, respectively, 66 and 56% of all patients. Tei et al. [17] reported on 'swallowing efficiency', and at 1-year post surgery, 22 of 25 patients (88%) had dysfunctional swallowing efficiency of liquids.

Overall, pharyngeal transit times at 1 year after surgery were deviant [16], especially in a cohort of patients with oropharyngeal cancer [10], and in this cohort, the oral transit time was too. In the majority of patients swallowing efficiency [17] and the oral and pharyngeal phase of swallowing were considered to be abnormal [16].

Another important outcome in analyzing swallowing function by means of videofluoroscopy is aspiration. Aspiration of liquids at 12 months after surgery was seen in 25% (8 of 32 patients) [16] and in 19% (4 of 21 patients) [10] of all patients. Thirty-four percent (11 of 32) [16] versus 24% (5 of 19) [10] showed no aspiration at all. The rest of the patients had penetration of liquids to the larynx. In the study of Tei et al. [17], 3 of 25 patients (12%) aspirated on liquids at more than 1 year post surgery. Chien et al. [15] reported that after at least 1-year post surgery 29 of 39 (sub)total glossectomy patients (74%) did not aspirate, 4 of 39 patients (10%) showed significant aspiration, and 6 of 39 (15%) had 'non-significant' aspiration. The specifics of this latter analysis, however, are not given. Aspiration rates more than 1-year post surgery range from 12 to 50% [10, 15–17].

Questionnaires

Three studies used questionnaires, i.e., the UW QoL questionnaire, used by Zuydam et al. [19] for 278 patients with oral cancer, and also used by Rogers et al. [20] for 561 oral and oropharyngeal cancer patients (of whom the cohort of 172 T3–4 oral cancer patients was selected). The EORTC QLQ H&N 35 questionnaire was used by Schoen et al. [21] (among other questionnaires), for 50 edentulous primary oral cancer patients.

In the study of Zuydam et al. [19], the longitudinal trend is that speech worsened at the first measurement (3 and 6 months after surgery). Then speech remained stable after 12 months or longer, but mean scores were significantly lower than before therapy. This is also the trend for patients receiving adjuvant radiotherapy (RT) in the study of Schoen et al. [21], but for patients who did not need RT, speech remained stable and relatively uncompromised. In both the cohorts, postoperative speech was worse for patients, who underwent RT compared to those, who did not have RT. Rogers et al. [20] reported no significant differences in this respect with 14 of 43 patients (33%) without adjuvant RT considering their speech the "same as always", and 9 of 46 (20%) with adjuvant RT.

In addition, with regard to swallowing, a significant difference between patients undergoing adjuvant RT and those who did not have RT was found in these three studies. Rogers et al. [20] showed that 33 of 43 patients without RT (77%) could swallow as before the surgery, compared to only 23 of 48 patients with RT (48%). In the RT group, 35% could swallow liquids only and another 35% could not swallow at all due to aspiration.

Mean swallowing score was reported to be already impaired before treatment [19, 21]. The trend in both cohorts of Schoen et al. [21] and Zudyam et al. [19] for swallowing for patients who underwent RT was that swallowing function worsens early post surgery. Mean scores improved slightly at 12 months post surgery, although they were still significantly lower than pretreatment scores in the largest cohort [19]. Schoen et al. [21] even showed improvement of swallowing function after surgery compared to the function before treatment in patients, who did not received RT. In the study by Zuydam et al. [19] a small deterioration in swallowing function was found for patients without RT, comparing the results before and 1 year after therapy. As could be expected, the higher the T-stage, the worse the swallowing function was after therapy.

Tei et al. [17] reported self-assessment of dysphagia in 25 postsurgical oral cancer patients. One year after surgery, no patient had a completely normal oral intake. The majority, 21 of 25 patients (84%) had mild dysphagia, but full oral intake, whereas the rest had moderate dysphagia and needed "supplemental nutrition".

In conclusion, subjective swallowing was impaired before and even more after surgery and adjuvant radiotherapy. Patients experienced minimal speech problems before treatment, although speech was also impaired after treatment, especially in patients receiving adjuvant radiotherapy.

Factors influencing speech and swallowing

Several studies reported that intelligibility is influenced by the area the resection took place. The areas which negatively influenced intelligibility are soft and/or hard palate [11, 19], tongue [9, 11], and resection of the posterior tongue/base of tongue [10, 19]. The more tongue tissue resected, the worse postoperative speech [11, 13]. However, Rieger et al. [14] showed that in their population of oropharyngeal cancer patients, intelligibility was not dependent on the size of the soft palate defect. Patients who underwent a combined soft palate/tongue resection [11] showed worse speech results, with a word intelligibility of

only 52%, compared to 81% in patients who had a soft palate resection only. Patients with floor of mouth tumors had the best nasality scores, patients with tonsil or soft palate tumors the worst [9]. Nasalance and aeromechanical results were dependent on the size of the soft palate resection [14]. Palatal prostheses enhanced speech in case of tongue [12] or soft palate resections [11], and free radial forearm flap reconstruction with 'soft palate insufficiency repair' (SPIR: the folded free radial forearm flap is attached to the posterior and lateral pharyngeal wall and slightly elevated, leaving a small nasopharyngeal orifice) for >1/2 soft palate defects [14] was better in this respect than to free radial forearm flap without 'SPIR'. Speech therapy improved postoperative speech [13] significantly for glossectomy patients.

Swallowing function was affected by the resection area as well. Oral tongue localization induced the least swallowing problems, whereas soft palate and base of tongue resections [10, 16, 19] showed the most prominent dysphagia. In the study of Tei et al. [17], in 25 patients with oral cancer, floor of mouth carcinomas induced the most severe swallowing dysfunction.

T-stage was also a strong factor. Higher T-stage was associated with worse speech and swallowing, measured objectively [9, 16] as well as subjectively by questionnaires [19].

Several other factors influenced the swallowing function. Co-morbidity turns out to be a negative factor for swallowing [16], and, as already mentioned above, adjuvant radiotherapy significantly further deteriorated swallowing function [19–21]. Free flap reconstruction yielded better results compared to pedicled flap reconstruction and finally, primary closure yielded better functional results than flap reconstruction [19].

Comparison of cohorts

To compare the functional results of different cohorts, a detailed description of the study is needed and tumor site and resection area should be noted. As described in this review, some studies reported one tumor site, such as base of tongue [10] or mobile tongue carcinomas [12, 13, 15]. The other cohorts included patients with tumors at several sub-sites in the oropharynx [14], oral cavity [17, 20, 21], or both [9, 11, 16, 19], resulting in a heterogeneous patient group.

Next to tumor site, T-stage is very important for the functional outcome. In the cohort of Bohle et al. [11], in 31% of the cases T-stage was unknown. However, this cohort was included because the number of patients with known T-stage was quite high. In the cohort of Zuydam et al. [19], 25% of patients had a T-stage <2, but this study was selected because results were presented per T-stage. Carvalho et al. [12] described a cohort of patients that underwent hemiglossectomy or larger resections, therefore, we included this study, although T-stages are unknown. Schoen et al. [21] described cohorts with smaller T-stages, which may explain their more favorable results. The patients in the cohort of Chien et al. [15] had tumors with higher T-stages, however, their results were remarkably good.

Discussion

Although during the last decades, a sizable number ($n = 1{,}220$) of papers concerning the functional consequences of and quality of life after surgical treatment of head and neck cancer have been published [6], only 12 studies could be identified that describe these aspects for advanced oral and oropharyngeal cancer thorough enough to warrant their inclusion in this systematic review. The fact that no papers could be identified in the earlier part of the search period, 1993 until 2001, underlines that only recently besides oncologic outcomes functional results are receiving more attention.

Evaluation of speech after surgery has shown that intelligibility remains quite good only if the mobile tongue and soft palate are not involved. In case of substantial tongue or soft palate resections [9, 11, 19], speech is reported to become deviant. The more tongue resected, the worse the postoperative speech intelligibility [11, 13]. This is not surprising given the anatomical change of the vocal tract, and with the mobile tongue being the most important articulator. A dysmorphic tongue challenges, e.g., the place of articulation.

Patients with tonsil or soft palate tumors had the worst nasalance rates, compared to patients with tumors at other locations of the oral cavity and oropharynx [9]. Resection of the soft palate and tonsil [14] may result in deterioration of the velopharyngeal function. A normal velopharyngeal function consists of closure of the nasal cavity by the pharyngeal walls and the soft palate, during speech, but also during, e.g., swallowing, blowing, or gagging. Impaired velopharyngeal function challenges the pronunciation of velar consonants (such as/k/) and hampers the regulation of (higher) intraoral air pressure needed for the articulation of, e.g., plosives (such as/p/,/t//k/). In the most severe cases velopharyngeal insufficiency may result in a compensatory change of the place of articulation and the occurrence of glottal stops instead [22]. Palatal prostheses [11, 12] and specific surgical reconstruction techniques of the soft palate [14] may enhance postoperative speech as it improves the velopharyngeal function.

An important aspect of postoperative speech is the alterations in the perception of speakers, who have been treated

with microvascular free flap reconstruction for oral or oropharyngeal cancer. Social perception is a process in which we assign attributes to others, with the speech signal playing an integral part in attribution. Rieger et al. [23] revealed that positive perceptions of speakers significantly diminished because of surgery, and negative perceptions increased. Certain variables, such as degree of resection of the soft palate and base of tongue, and sex of the speaker, influenced the results. This suggests that intelligibility measurements of speech, although useful, do not provide a complete indication of the social impact of reconstructive surgery on patients with oropharyngeal resections.

Results of this review show that sentence intelligibility scores of surgically treated patients with oral and oropharyngeal cancer are quite high, indicating that patients are satisfactorily understood in practice. However, this does not reflect normality of speech and communication. The reviewed research also indicates that word intelligibility rates are significantly compromised and nasality and articulation are deviant in the majority of patients, as is intelligibility of (spontaneous) text. Probably, alterations in speech functioning did not lead to diminished sentence intelligibility because of redundancy. In sentence intelligibility, the influence of syntactic–semantic information is important, as with this additional information, the intelligibility of single words might become redundant. Therefore, although sentence intelligibility appears to be normal, patients still may suffer from compromised oral function and "abnormal" speech, shown by, e.g., several small misarticulations, resonance disturbances, a hoarse voice, and loss of facial harmony, causing an altered perception in social communication. This is also suggested by the deviant nasality and articulation rates and diminished word intelligibility in postsurgical oral and oropharyngeal cancer patients, as found by several authors [9–12].

Besides speech, also swallowing can be impaired after surgical therapy for oral and oropharyngeal cancer, and the reviewed literature suggests that swallowing is affected notably worse. These functional impairments obviously are important for the quality of life for patients. This is clearly underlined by the study of Zuydam et al. [19], in which patients ranked various functional UW-QoL issues, and they ranked problems with saliva, chewing, speech, and swallowing as the most important issues following their treatment. Not surprisingly, immediately after surgery, swallowing function is worse, but it is reported to improve a little over time, measured objectively as well as subjectively. An important parameter of swallowing 'normalcy' is the pharyngeal transit time (PTT). PTT's are found to be significantly delayed, especially when oropharyngeal resection is followed by adjuvant radiotherapy [10]. Aspiration is the ultimate, potentially life-threatening swallowing problem, and aspiration rates vary between 12 and 50%. Swallowing disorders postoperatively were most prominent when significant parts of the soft palate and base of tongue were resected. One small study [17] finds also that floor of mouth resections induce swallowing problems, which is not supported by the other studies.

Comparison with organ-sparing therapies

Functional results after surgical therapy should be compared to functional results after organ sparing therapies, as this is the other curative therapy option. Van der Molen et al. [24] show that after chemoradiation for head and neck cancer the swallowing disorders are moderate to very severe, aspiration rates after therapy increase to 23–78%. This illustrates that despite organ sparing results of concomitant chemoradiation, the risk on functional sequelae is still considerable [25]. The most common long-term complication is dysphagia, caused by damage to the base of tongue and pharyngeal wall after severe mucositis, radiation induced fibrosis, xerostomia and radiation necrosis [25–28].

Speech, however, appears to be relatively uncompromised [4, 26, 29] and might be better after treatment with chemoradiation compared to surgical therapy.

Limitations of this literature review

In our selection, there were two retrospective cohort studies and ten prospective cohort studies. The size of the cohort varied from 25 to 278. In total, this review comprises of 856 patients. However, since most cohorts were relatively small, 5 of the 12 studies have patients groups consisting of less than 40 patients, one has to keep in mind that especially the results of these cohorts may be less reliable.

Papers were selected following an evaluation of relevance and risk on bias. As only four papers were scored A/A also papers scored A/B were selected, with moderate risk on bias. According to Cochrane criteria, studies should be rated as B when one or more of the predefined criteria were partly met. The papers were also rated as B when only one criterion was not met, because the criteria were very stringent and detailed. The criteria that were considered of utmost importance were clear description of the patient group with regard to T-stage, tumor site, and extension, and extent of resection. A publication bias [30] might also play a role in the favorable outcomes of all these studies. It is realistic to assume that unacceptable functional results are less likely to be published.

The most important limitation of this review is that results remain mainly descriptive, and that pooling of results is not possible, as ways of outcome measurements differ. This is the reason that this review does not provide an overall picture. However, conducting a review aiming at

comparable outcome measurements would result in more heterogeneous patient groups, lowering chances for making scientific conclusions. Therefore, this descriptive review is an attempt to evaluate the present knowledge of functional results after surgery for advanced oral and oropharyngeal cancer, although it does not provide an unambiguous result.

Objective versus subjective outcomes

None of our articles reported both on outcomes of objective measurements of function and on outcomes retrieved by validated quality of life questionnaires. Only Tei et al. [17] reported swallowing efficiency based on videofluoroscopy combined with a (non-validated) self-assessed dysphagia grading. It appeared that these outcomes correlated, although some patients with severely deviant swallowing efficiency had a remarkable low dysphagia grading, namely a mild dysphagia and nutrition by an easy chewable diet.

Borggreven et al. [31] described in another paper subjective outcomes in the same patient group. They concluded that most general health related quality of life issues do not change after treatment, or improve compared to baseline scores (which are already deviant from a 'normal' population). Most head and neck specific issues deteriorate after treatment but return to pretreatment levels at 12 months, except for senses, opening mouth, sticky saliva, and coughing which remain deteriorated in the long term. Speech and swallowing return to pretreatment levels as well. This shows a discrepancy with the objectively measured outcomes, demonstrating a compromised function after therapy.

Several factors, such as tumor site, age, co-morbidities, and reconstruction method seemed to have an effect on the quality of life after surgery [31, 32]; for example women and young patients report in subjective studies more functional problems [33]. It remains difficult to link quality of life with function. Even in patients with laryngeal cancer, where comparison can be made between patients with and without laryngeal speech, it is difficult to link function and quality of life [34].

Besides postoperative oral function, many other factors influence quality of life. Although a relation between functional status and quality of life has been suggested [35], it certainly is not yet established. Therefore, we suggest that studies regarding function after surgery should include both objective and subjective outcomes. By using both clinical and patient-rated scores it is possible to gain a better judgment of clinical functional defects.

Outcome measurements

In the head and neck oncology literature, there is a lack of uniformity in measurements of oral function. Standardization is imperative to be able to compare functional outcomes published in different studies. Mlynarek et al. [8] propose that functional data should be collected at several points in time, including pretreatment. Swallowing should be assessed via modified barium swallows, diet history, weight and presence or use of a gastrostomy tube. Speech intelligibility could be assessed via the Computerized Assessment of Intelligibility of Dysarthric Speech and quality of life via the EORTC QLQ H&N 35 and the MDADI [8]. There are several other good ways of measuring functional outcomes, but uniformity is important. Use of standard outcome measurements internationally would lead to a better understanding of functional outcomes after treatment for head and neck cancer. However, one has to keep in mind that additional study- and disease-specific questionnaires often are needed to be able to assess speech (and swallowing) function satisfactorily [36].

Clinical implications of this review

Obviously, impairments of speech and swallowing after surgery within the vocal tract and the first part of the alimentary tract have to be taken into account, as the reviewed studies clearly have shown, especially when the tumor invades the soft palate and the base of tongue. This is an important issue for clinicians when counseling patients with an advanced oral cavity and/or oropharyngeal tumor invading significant parts of the mobile tongue, the soft palate and the base of tongue. Obviously, no general definition of functional inoperability can be given (yet), as multiple factors play a role and thoughts about what is functional inacceptable will obviously vary per patient, physician and hospital. Nevertheless, based on the findings of this review, critical areas for functional inoperability have been defined.

Conclusion

Speech after surgery for advanced oral and oropharyngeal carcinoma seems moderate to good, but the results are difficult to compare in numbers due to different outcome measurements. The negative effects of surgery with regards to swallowing are nevertheless more prominent and more severely affecting quality of life. The reviewed studies also show that adjuvant RT has an additional detrimental effect on swallowing and speech. Besides adjuvant RT, other important factors influencing functional outcomes are T-stage, co-morbidity, and method of reconstruction. Most speech problems were seen in patients with tumors located in the mobile tongue, the base of tongue and/or the soft palate. Most postoperative swallowing problems were seen in patients operated on tumors in the base of tongue and/or the soft palate.

Conflict of interest statement None.

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