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Computer-assisted documentation of the fiberoptic endoscopic evaluation of swallowing

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A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Summary

Background: Because documentation and report writing in fiberoptic endoscopic evaluation of swallowing (FEES) is time consuming and susceptible to omissions, a software solution to ameliorate these problems by maintaining document quality is desirable.

Material/Methods: Based on the FEES procedure of Langmore, a documentation software (DS) which presents a digitized FEES recording and masks with precast text fields was designed to facilitate and unify data input. The oropharyngeal secretion scale of Murray and the penetration-aspiration scale of Rosenbek were integrated to increase comparability of dysphagia information. Four independent examiners analyzed 12 digitized FEES-recordings, 6 without and 6 with the DS, to determine its effect on the times needed for total evaluation, interpretation, documentation, report writing, and report completeness.

Results: The documentation software (DS) reduced the total evaluation time from 42 min to 18 min and increased the evaluation completeness from 55% to 95%, both with very large effect sizes. The time saving was mainly due to an automated report generation at the end of the analysis.

Conclusions: The DS can be offered as a valuable and effective tool in daily clinical routine and for research purposes.

key words: **fiberoptic endoscopic evaluation of swallowing • FEES • computer-assisted documentation • dysphagia • swallowing disorders**

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BACKGROUND

The fiberoptic endoscopic evaluation of swallowing (FEES) is a frequently used and widely appreciated diagnostic procedure to explore the deglutition process [1–4]. The reliability and efficacy increased with the integration of videotape recording into the procedure [5,6] and the implementation of a comprehensive FEES protocol [7,8]. However, the proper and complete performance of a FEES examination and its scoring is not self-evident and thus not consistent between users even though Langmore [9] trademarked the term FEES to ensure procedural fidelity and completeness and to distinguish it from a simple laryngeal screening to identify merely aspiration. In terms of evidence-based medicine health professionals ought to speak the same language [10] which requires a consistent performance and documentation of the FEES procedure.

FEES requires (1) the description of anatomy and biomechanical function of the critical structures, (2) the direct examination of swallowing food and liquids, and (3) therapeutic maneuvers tried and their effects [11]. The observance of all these required items during examination and documentation as well as their consideration in a final report is time consuming and difficult to complete in the clinical routine. Although various software and computer assisted solutions have been made available for different purposes in diverse medical fields [12–15] and modern video and computer technology facilitates the FEES examination, a qualified computer aided system to support a reliable data evaluation by enhancing time effectiveness in FEES is still missing.

The aim of this study was (1) to design a software solution which facilitates the interpretation and documentation of the FEES procedure and enhances the productivity by maintaining high quality of an automated generated final report, and (2) to quantify the time savings and improvements in report quality by the use of this system.

MATERIAL AND METHODS

Material

The DS was programmed by C++, is based on the FEES protocol of Langmore 2001 [16], and integrates all of its items. The digitized FEES recording is displayed and can be replayed by demand either with normal speed or frame by frame.

The DS is divided into just two parts: anatomic-physiologic assessment and direct examination of swallowing food and liquids. (1) The anatomic-physiologic assessment describes in detail the morphological findings and biomechanical functions of the critical structures (velum and epipharynx, base of the tongue and mesopharynx, larynx and hypopharynx) as well as its sensory integrity and oropharyngeal secretions (see Appendix 1). (2) The direct examination of swallowing food and liquids concerns leaking, penetration and aspiration, and residues, with special regard to different consistencies and bolus volumes (see Appendix 2). This part includes the third component of FEES, that is, the therapeutic tries and their effects for every checked consistency and bolus volume.

Both parts are arranged in subordinate sections with different screens obtainable by mouse click. The order of the subsections with its appropriate windows corresponds to the chronological order of the deglutition sequence and to the examination process. Each part of these subsections contains a task-tailored checklist of frequent pathological findings (Figure 1).

For most checklist items, the appropriate findings have just to be marked by a click. If findings cannot be documented via checklist, a text field for notes is available. If there is no pathological finding, a button labelled 'normal' has to be clicked which deactivates the task-tailored checklist so that the analyzer can carry on with the next part. In case of unsatisfactory patient cooperation a button labelled 'not realizable' opens a drop-down menu with a list of the most frequent reasons for insufficient compliance, and the corresponding task-tailored checklist is deactivated. Illustrative stills of the recording can be placed into provided placeholders, especially when salient findings are difficult to describe. After completing the first part the program returns to the main menu and marks the edited part as completed.

By starting the second part of the DS, the examiner first has to mark the realized tests with respect to consistencies and bolus volumes. The following program opens just the chosen screens to carry on the analysis of the direct examination of swallowing food and liquids. This feature enables the DS to document the patient-tailored examination process of FEES completely and time-efficiently without unnecessary non-applicable documentation procedures. Each swallow is judged in the oral and pharyngeal stage with regard to the fiberoptic view (Figure 2).

Two scoring parameters are included to grade the severity of dysphagia: The 4-point rating scale of Murray for determining the severity of accumulated oropharyngeal secretions [17], and the 8-point penetration-aspiration scale (PAS) of Rosenbek [18]. The latter allows for a comparison between FEES and VFSS studies [19,20].

Evaluation procedure

Twelve FEES examinations of dysphagic patients (six with neurological diseases, six with head and neck cancer) were performed by the first author (endoscope 11101 RP2, Karl Storz GmbH, Tuttlingen, Germany) and digitally recorded with the ENT video endoscopy system EndoStrob-DX (Xion medical GmbH, Berlin, Germany).

After an introduction into the DS, four independent examiners (two otolaryngologists, a speech-and-language pathologist, and an oral-maxillofacial surgeon, all experienced in FEES) analyzed the 12 digital FEES recordings, six without DS (evaluation system No DS) and six with DS (evaluation system DS). The selection of FEES recordings were taken from a convenience sample of patients which can be considered representative for the main etiologies of deglutition disorders seen in the clinic. Individual patient characteristics and respective film length are shown in Table 1.

The mean film lengths differed slightly but not significantly between the two evaluation systems, as tested with the Mann-Whitney U test. For group No DS the mean film length was 334 seconds (range 249 to 426 seconds), for group DS 388

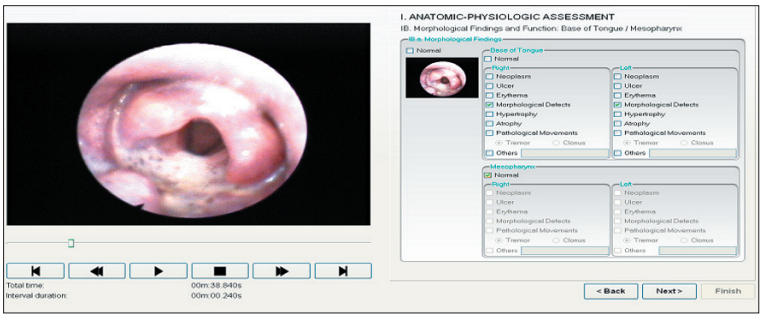

Figure 1. Example of the DS part (1): anatomic-physiologic assessment.

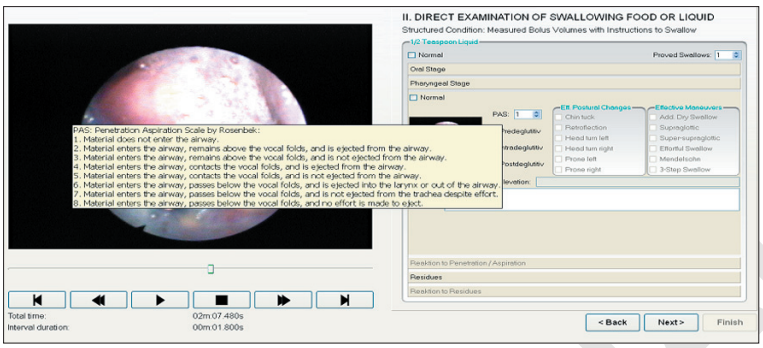

Figure 2. Example of the DS part (2): direct examination of swallowing food and liquids.

Table 1. Patient characteristics (age in years, sex, etiology) and film lengths for the NoDS and DS condition.

No DS				DS			
Patient's			Film length (sec)	Patient's			Film length (sec)
Age	Sex	Etiology		Age	Sex	Etiology	
56	m	Brainstem stroke	370	71	M	Stroke	380
62	m	Parkinson disease	433	69	M	Craniocerebral trauma	332
38	m	Cerebellum stroke	446	84	F	Stroke	363
67	m	Oropharynx cancer	330	50	M	Larynx cancer	249
49	m	Oropharynx cancer	509	70	M	Larynx cancer	426
64	m	Larynx cancer	240	67	M	Oropharynx cancer	256

seconds (range 240 to 509 seconds). To avoid serial effects the films were arranged in a balanced order. The films were viewed in real time, with slowed speed, or frame-by-frame with or without repeated viewing depending on the individual examiner need. The evaluation system constituted the main independent variable.

Five criteria were quantified and were the dependent variables: (1) total evaluation time (total time needed for interpretation, documentation, and writing a final report), (2) interpretation time, (3) documentation time, (4) time for writing a final report, and (5) completeness of reported parameters required by the original FEES protocol.

Statistical analysis

A General Linear Model analysis was calculated to determine the effect of the evaluation system and examiner as well as the interaction effects on criteria (1) to (5). Although each examiner used both evaluation systems, she did so with a different film each time. Therefore, the independent variable of evaluation system (No DS or DS) was considered a between-subject variable.

Results

Table 2 shows means of the different dependent variables, specified above as criteria (1) to (5), for each evaluation system, and the means and standard deviations over examiners.

As to total evaluation time, a 2 (Evaluation System: No DS vs DS) by 4 (Examiners) General Linear Model (GLM) showed a main effect for Evaluation System [$F(1,40) = 136.91$, $p<.000$, $\eta_p^2=.77$], a main effect for Examiner [$F(1,40)=41.88$, $p<.000$, $\eta_p^2=.76$], and a significant interaction Evaluation System by Examiner [$F(1,40)=13.84$, $p<.000$, $\eta_p^2=.51$] (Figure 3).

Table 2. Means for the five dependent variables for NoDS vs DS: total evaluation time (min;sec), time for interpretation, for documentation, and for writing final report, and mean report completeness in% (±SD) over examiners.

Parameter	Examiner 1		Examiner 2		Examiner 3		Examiner 4		Mean over examiners	
	DS		DS		DS		DS		DS	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Total evaluation time	36.22	24.47	70.54	25.30	24.19	9.01	37.58	14.54	42.23±19.09	18.32±9.02
Time for interpretation	10.56	15.36	24.06	23.36	7.08	5.21	10.00	8.36	13.02±9.32	12.18±7.13
Time for documentation	9.21	5.47	22.09	6.14	7.41	3.08	11.49	5.14	12.45±6.36	4.35±1.41
Time for writing final report	16.04	3.41	24.39	5.50	9.29	0.31	16.09	1.03	16.36±6.18	1.38±1.32
Report completeness (%)	48.40	82.10	70.30	90.20	39.00	93.90	62.20	96.40	54.98±14.65	94.8±4.3

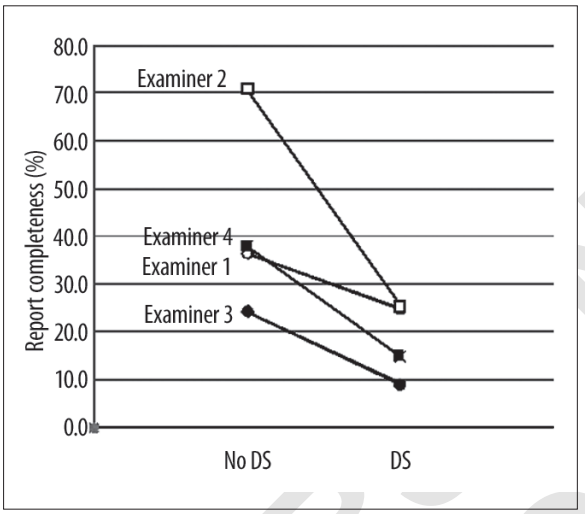

Figure 3. Mean of the total evaluation times (min) for the four examiners NoDS vs DS.

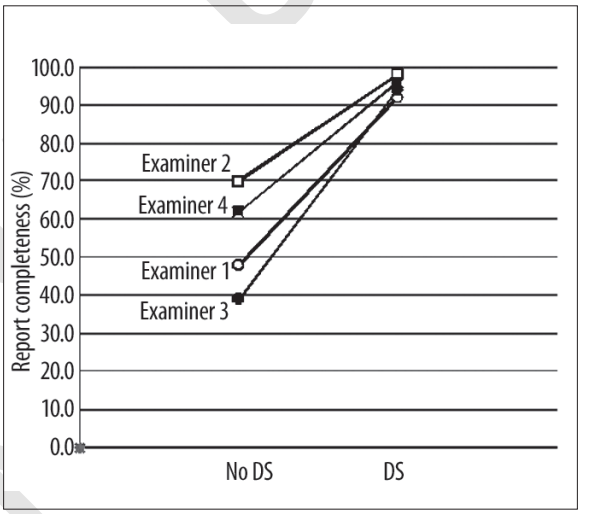

Figure 4. Mean of the report completeness (%) for the four examiners NoDD vs DS.

In order to determine the contributions of the single time components (time for interpretation, documentation, report writing) to the total evaluation time, a GLM was calculated for each of them. For the interpretation time neither the main effect of the Evaluation System nor the interaction Evaluation System by Examiner was significant. The main effect of Examiner, however, was significant [$F(1,40)=14.68$, $p<.000$, $\eta_p^2=.52$]. For documentation time, all three effects were very significant: Evaluation System [$F(1,40)=111.77$, $p<.000$, $\eta_p^2=.74$], Examiner [$F(1,40)=18.11$, $p<.000$, $\eta_p^2=.58$], and Evaluation System by Examiner [$F(1,40)=18.47$, $p<.000$, $\eta_p^2=.58$]. For report time, all three effects were very significant: Evaluation System [$F(1,40)=441.85$, $p<.000$, $\eta_p^2=.92$], Examiner [$F(1,40)=22.11$, $p<.000$, $\eta_p^2=0.62$], and the interaction Evaluation System by Examiner [$F(1,40)=17.59$, $p<.000$, $\eta_p^2=.57$].

For the completeness of report, all three effects were very significant: Evaluation System [$F(1,40)=442.10$, $p<.000$, $\eta_p^2=.92$], Examiner [$F(1,40)=18.30$, $p<.000$, $\eta_p^2=.58$], and Evaluation System by Examiner [$F(1,40)=9.91$, $p<.000$, $\eta_p^2=.43$] (see Figure 4).

There was no correlation between the order of the evaluated film per examiner and any of the dependent variables, thus excluding serial effects (e.g. learning, fatigue).

Discussion

The DS decreases the evaluation time of FEES by large effect sizes and at the same time increases the completeness of the evaluation. The mean of the total evaluation time including the final report, averaged for all four examiners, decreased from more than 42 minutes to less than 19 minutes by using the DS. This decrease is impressive in light of the fact that a partial eta^2 larger than .14 counts already as a large effect size [21], and partial eta^2 of .77 for the time gain afforded by the documentation software was obtained here. The reduction in total evaluation time is due to time savings mostly for the documentation and for the final report. Averaged over all four examiners, the mean documentation time decreased from more than 12 minutes to less than 5 minutes, the mean time for writing the final reports from more than 16 minutes to less than 2 minutes.

The completeness of the examination, as documented in the final report, increased from 55% to 95%, due to the

requirement that all parameter of the program must be clicked and ticked in order to get the automatically generated final report. The completeness was short of hundred percent because not all possible findings and their parameters could be manageably and economically offered with fixed answer formats just to be clicked. Minor or rare findings, that is, the well-known "others" category, could but had not to be entered into a free-text field for the program to proceed. The free-text fields left unanswered account for the missing percentage of completeness.

The benefit of the software was obvious for all four examiners, even if a significant statistical interaction between evaluation system and examiner existed for the time required for total evaluation, documentation, and report writing as well as report completeness. One examiner (Examiner 3) profited enormously regarding report completeness. Another one (Examiner 2), who was already proficient in writing complete reports, accelerated significantly the total evaluation time by using the software. The use of the software, however, could not reduce the average time for interpretation. The time requirement for interpreting findings seems to depend on examiner characteristics like inclination for precision and work pace.

In addition to the decreased evaluation time and increased completeness, it can be assumed that the repeated use of the DS increases examination quality by anticipation of checkpoints even if the program is discontinued.

Conclusions

The fiberoptic endoscopic evaluation of swallowing (FEES) is worldwide appreciated for the assessment of the deglutition process. As recording techniques and computers get advanced and modernized to facilitate the examination, a modern evaluation of FEES data with a qualified electronic data processing system is still lacking.

The presented DS enables its user to enhance the time efficiency and the quality of FEES evaluation. Besides a handy and complete data acquisition, the implementation of the automated report generation function qualifies the DS to increment the productivity and to facilitate the daily routine. Therefore the DS can be offered as a valuable tool for clinical and scientific purposes in the evaluation of dysphagia.

Appendix 1

Part 1 of the DS: Evaluated parameters of anatomic--physiologic assessment.

Evaluation of morphological findings and function:
Velum and epipharynx, base of tongue and mesopharynx, larynx and hypopharynx.
Checklist entries for morphological findings:
Neoplasm, ulcer, erythema, morphological defects, hypertrophy, atrophy, asymmetry involuntary movements at rest.
Checklist entries for function (movement qualities for every evaluated task):
Symmetry, limitations in: speed, range and coordination.
Evaluated function and tasks:
Velar and lateral wall movements.
Tasks: velopharyngeal closure by dry swallow and phonation.
Retraction of base of tongue.
Tasks: dry swallow, repeating of postvocalic /l/ word like "earl".
Movement of pharynx, constrictors and longitudinal.
Tasks: phonation of strained loud high /ee/ and repeated /ee/.
Abduction and adduction of true vocal cords.
Tasks: respiration and phonation: repeated /ee/.
Airway protection.
Tasks: true vocal folds closure: breath-holding lightly (7+sec), false vocal folds closure: breath-holding tightly, cough, epiglottal inversion: dry swallow.
Secretions and spontaneous swallowing:
Locations of oropharyngeal secretions, appearance of secretions (colour, viscosity), awareness to secretions, patient's response, frequency of spontaneous swallows.
Sensation and sensory testing:
Response to presence of endoscope, response to light touch of certain structures.

Appendix 2

Part 2 of the DS: Direct examination of swallowing food and liquids.

Oral stage (fiberoptic endoscopic view):
Competence of linguovelar seal, base-of-tongue movements, base of tongue propulsion, bolus transport into the pharynx, duration of complete oral stage.
Premature spillage of bolus parts: bolus path, initiation of swallow, penetration/aspiration.
Pharyngeal stage:
Checklist entries for different bolus consistencies and bolus volumes:
Measured bolus volumes with instructions to swallow:
Bolus path, swallow initiation, penetration/aspiration, pre-, intra-, and postdeglutitive.
Natural drinking and eating behaviour:
Bolus path, swallow initiation, penetration/aspiration, pre-, intra-, and postdeglutitive.
Hyolaryngeal elevation: epiglottal inversion (impression from all swallows).
Residues and management:
Checklist entries include the different bolus consistencies and bolus volumes:
Location of residues, amount of residues, awareness to residues, clearing forces, effectiveness of clearing forces.

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