→①「ありの方は，その内容についてご記載ください。

| |
|---|
| |

問２　入居者（利用者）への食事介助について，あてはまる番号に○をつけてください。

1．食事介助を行う入居者（利用者）について確認していること

| | よくしている | ときどきしている | あまりしていない | まったくしていない |
|---|---|---|---|---|
| 1.　年齢 | 1 | 2 | 3 | 4 |
| 2.　疾患名（病名） | 1 | 2 | 3 | 4 |
| 3.　飲み込みの状態 | 1 | 2 | 3 | 4 |
| 4.　食品，味付けなどの好み | 1 | 2 | 3 | 4 |
| 5.　食事の形態 | 1 | 2 | 3 | 4 |
| 6.　過去に誤嚥性肺炎を起こしているか | 1 | 2 | 3 | 4 |
| 7.　平均的な食事量 | 1 | 2 | 3 | 4 |
| 8.　体重の変化 | 1 | 2 | 3 | 4 |
| 9.　感染症があるか | 1 | 2 | 3 | 4 |
| 10.　要介護度 | 1 | 2 | 3 | 4 |
| 11.　認知機能 | 1 | 2 | 3 | 4 |

1-1　そのほか，確認していることがありましたらご記載ください。

| |
|---|
| |

2.　食事介助の前に確認すること

| | よくしている | ときどきしている | あまりしていない | まったくしていない |
|---|---|---|---|---|
| 1.　口の中が汚れていないか | 1 | 2 | 3 | 4 |
| 2.　義歯（入れ歯）を付けているか | 1 | 2 | 3 | 4 |
| 3.　夜間に咳があるか | 1 | 2 | 3 | 4 |
| 4.　排便の状態（下痢，便秘など） | 1 | 2 | 3 | 4 |
| 5.　リハビリ，レクリエーションなどの活動量 | 1 | 2 | 3 | 4 |
| 6.　夜間の睡眠状況 | 1 | 2 | 3 | 4 |
| 7.　体調（顔色など） | 1 | 2 | 3 | 4 |
| 8.　目がさめているか（覚醒の状態） | 1 | 2 | 3 | 4 |

2-1　そのほか，確認していることがありましたらご記載ください．

| |
|---|
| |

3.　食事介助中に確認すること

| | よくしている | ときどきしている | あまりしていない | まったくしていない |
|---|---|---|---|---|
| 1.　目がさめているか（覚醒の状態） | 1 | 2 | 3 | 4 |
| 2.　意思の表出があるか | 1 | 2 | 3 | 4 |
| 3.　指示に対する反応があるか | 1 | 2 | 3 | 4 |
| 4.　食欲があるか | 1 | 2 | 3 | 4 |
| 5.　流涎（よだれ）があるか | 1 | 2 | 3 | 4 |
| 6.　姿勢が安定しているか | 1 | 2 | 3 | 4 |
| 7.　食事の介助量（全介助・部分介助など） | 1 | 2 | 3 | 4 |
| 8.　食物によるむせがあるか | 1 | 2 | 3 | 4 |
| 9.　水分をのむときにむせがあるか | 1 | 2 | 3 | 4 |
| 10.　口の中に食べ物が残っていないか | 1 | 2 | 3 | 4 |
| 11.　硬いものが食べにくくなっていないか | 1 | 2 | 3 | 4 |
| 12.　食べこぼしがあるか | 1 | 2 | 3 | 4 |
| 13.　飲みこむときに首が前傾しているか | 1 | 2 | 3 | 4 |
| 14.　食べるペースが変わっていないか | 1 | 2 | 3 | 4 |

3-1　そのほか，確認していることがありましたらご記載ください．

| |
|---|
| |

4.　入居者（利用者）が飲み込んだかどうか，どのように確認していますか．

| 例）口のなかの食べ物がなくなったとき，のどが動いたとき，など |
|---|
| |

5. 食事介助の後に確認すること

| | よくしている | ときどきしている | あまりしていない | まったくしていない |
|---|---|---|---|---|
| 1. 呼吸の状態 | 1 | 2 | 3 | 4 |
| 2. 痰がからんでいないか | 1 | 2 | 3 | 4 |
| 3. 食事時間がいつもより長くなっていないか | 1 | 2 | 3 | 4 |
| 4. 胃から食物や胃液が逆流していないか | 1 | 2 | 3 | 4 |
| 5. 食べ物がつかえる，詰まっている様子がないか | 1 | 2 | 3 | 4 |
| 6. 口腔内に食物が残っていないか | 1 | 2 | 3 | 4 |
| 7. 体調の変化や気分の不快感がないか | 1 | 2 | 3 | 4 |

5-1　そのほか，確認していることがありましたらご記載ください.

問3 食事介助で困っていることや，改善した方がよいことなどがあれば自由に書いてください.

例）口のなかに食べ物をためてしまう方の食事介助，むせ込みやすい場合にはどうすればよいかなど

問4 下記の質問に対し，該当する番号に○を付け，該当する内容についてご記載ください.

1. 現在の仕事に就く前に，学校（大学，短期大学，専門学校）や講習会などで，食事介助や嚥下障害などの講義や演習を受けたことがありますか.

① あり　　②なし

→①「あり」の方は、その内容についてご記載ください。

| |
|---|
| |

2. 仕事で食事介助を行うようになってから，食事介助や摂食・嚥下障害などに関する研修会に参加たことがありますか.

| |
|---|
| ①あり　②なし |

→①「あり」の方は、下記についてお答えください。

2-1　主な研修内容についてご記載ください.

| |
|---|
| |

2-2　研修には，誤嚥や窒息などの緊急時の対応についての内容は含まれていましたか.

| |
|---|
| ① あり　②なし　③覚えていない |

2-3　食事介助や摂食・嚥下障害に関する研修会があれば，参加したいと思いますか.

| |
|---|
| ① 参加したい　②参加しない　③わからない |

→①「参加したい」と答えた方は，どのような研修内容を希望しますか.

| |
|---|
| |

3. これまで吸引に関する講義や演習（実施）を受けたことがありますか.

| |
|---|
| ①あり　②なし |

4. 食事介助中に，入居者（利用者）が食物を上手く飲み込めているか確認できる機器があれば，使用したいと思いますか（例 頸部に着用して，飲み込んだ後に光る機器など）.

| |
|---|
| ①使用したい　②使用したいと思わない　③どちらともいえない |
| ④その他（　　　　　　　　　　　　　　　　　　　　） |

問5　あなたご自身のことについて，あてはまる番号に○印，または数字をご記入ください．

1．性別

| |
|---|
| ①男性　　　　②女性 |

2．年齢

| |
|---|
| ①10 歳代　②20 歳代　③30 歳代　④40 歳代　⑤50 歳代　⑥60 歳代 |
| ⑦70 歳代以上 |

3．職種（お持ちの資格すべてに○をつけてください．複数回答可）

| |
|---|
| ①看護師　②准看護師　③介護福祉士　④ヘルパー（　　　級） |
| ⑤介護職員初任者研修課程修了　⑥資格なし　⑦そのほか（　　　　　） |

4．就業形態

| |
|---|
| ①常勤　②非常勤・パート　③そのほか（　　　　　　　） |

5．資格はどのように取得されましたか（複数回答可）．

| |
|---|
| ①大学　②短期大学　③専門学校　④通信教育 |
| ⑤都道府県や市町村主催の講習　⑥そのほか（　　　　　　　） |

6．仕事として食事介助を行うようになってからの年月（休職期間などを除いたのべ年数）．

| |
|---|
| 約（　　　）年（　　　）カ月　（2014 年 11 月 1 日現在） |

問6 高齢者の食事介助や摂食・嚥下障害について疑問なことや，本調査への意見や感想などがありましたら自由に書いてください．

| |
|---|
| |

お忙しいなか，調査にご協力いただきまして本当にありがとうございました．

別添５

研究成果の刊行に関する一覧表

書籍

| 著者氏名 | 論文タイトル名 | 書籍全体の編集者名 | 書　籍　名 | 出版社名 | 出版地 | 出版年 | ページ |
|---|---|---|---|---|---|---|---|

雑誌

| 発表者氏名 | 論文タイトル名 | 発表誌名 | 巻号 | ページ | 出版年 |
|---|---|---|---|---|---|
| Jayatilake, D.<br>Suzuki, K.<br>Yohei, T.<br>Ueno, T.<br>Nakai, K.<br>Hidaka, K.<br>Eguchi, K.<br>Ayuzawa, S.<br>Matsumura, A. | Swallowscope: A Smartphone based Device for the Assessment of Swallowing Ability | Proc. of IEEE-EMBS International Conference on Biomedical Health Informatics | - | 697-700 | 2014 |

６．研究成果による特許権等の知的財産権の出願・登録状況

特になし

７．健康危険情報

・本研究の遂行にあたり，健康危険情報は認められなかった．

# Swallowscope: A Smartphone based device for the Assessment of Swallowing Ability

Dushyantha Jayatilake[1], Kenji Suzuki[1], Yohei Teramoto[2], Tomoyuki Ueno[2], Kei Nakai[2]
Kikue Hidaka[2], Satoshi Ayuzawa[3], Kiyoshi Eguchi[2] and Akira Matsumura[2]

***Abstract*— Dysphagia can cause serious challenges to both physical and mental health. Aspiration due to dysphagia is a major health risk that could cause pneumonia, and even death. As a result, monitoring and managing dysphagia is of utmost importance. This study investigates the development of a smartphone-based device and a feasible real-time swallowing sound processing algorithm for the automatic screening for swallowing ability.**

**The videofluoroscopic swallow study (VFSS), which is considered the gold standard for the diagnosis of dysphagia, is not widely available, expensive and causes exposure to radiation. The screening tests used for dysphagia need to be carried out by trained staff and the evaluations are often non-quantifiable. The Swallowscope we developed is a wearable device based on mobile health, and uses the swallowing sound to quantitatively evaluate swallowing ability. As swallowing sound can be captured continuously and during activities of daily life with minimal intervention, it is an ideal approach to monitor swallowing activities, and its continuous monitoring has a better probability of capturing aspirations and risky swallow patterns.**

**This paper describes the real-time smartphone based algorithm and the application we developed to monitor swallowing activities and evaluates the recognition accuracy by comparing them with VFSS evidence.**

## I. INTRODUCTION

Deglutition, which is commonly known as swallowing, is a complex neuromuscular process that consists of both voluntary and reflexive actions of approximately 50 paired muscles [1]. The swallowing process can be divided into 3 phases: the oral phase, the pharyngeal phase and the esophageal phase, and dysphagia or difficulties in swallowing can result from a wide variety of functional or structural deficits in each of these phases. Most common of these causes are diseases and disorders such as strokes, neuromuscular diseases (e.g. Parkinson's disease and Amyotrophic lateral sclerosis or ALS), and cancer. Dysphagia could be both congenital and acquired and more common with the elderly. The medical, social, and psychological impacts of dysphagia could be serious. Aspiration, which is the misdirection of oropharyngeal or gastric contents into the larynx instead of the stomach, can cause pneumonia, in particular with the immunocompromised patients. In Japan, the upward trend of deaths due to pneumonia has risen to the 3rd place of leading causes of death by 2011 with 98.9 deaths/100000 people [2], and with the ageing population in Japan, this rate is expected to increase even further. Furthermore, inability to eat properly can adversely affect the health through dehydration and malnutrition, and it can also affect the quality of life [3], [4]. Dysphagia is also the most common symptom of esophageal cancer, and its early detection is crucial for the successful prognosis [5].

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[3] S. Ayuzawa is with the Tsukuba University of Technology, 305-8521, Japan

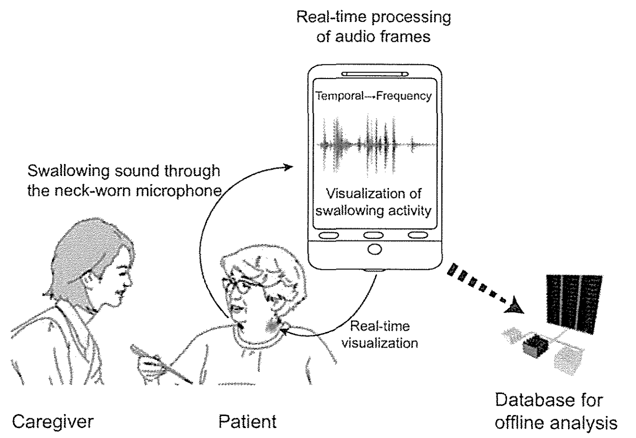


Fig. 1. The Swallowscope for the continuous monitoring of swallowing activities at the bedside and during activities of daily life

The videofluoroscopic swallow study (VFSS) is considered the gold standard for the diagnosis of dysphagia. VFSS, which is also known as the modified barium swallowing examination (MBS), captures sequential video-radiographic images of barium contrast-impregnated food and liquid as they are transported during the oral cavity, pharyngeal cavity, and esophagus in real-time. However, VFSS is needed to be performed by trained staff at designated facilities, and is subjected to exposure to radiation. Furthermore, the assessment is more qualitative and requires expert knowledge to interpret it. It is also imperative that clinicians observe patients during their usual eating and drinking environment to determine the external validity of the examination results and to assess the patient's ability to carry-over any learned swallowing strategies [6]. Considering those various complexities, some researchers such as Leder et.al [7] have suggested the use of screening techniques prior to the use of VFSS.

Screening tests for dysphagia are intended to find the individuals who are strongly suspected of having dysphagia. Dry swallowing, Repetitive saliva swallowing test (RSST), Water

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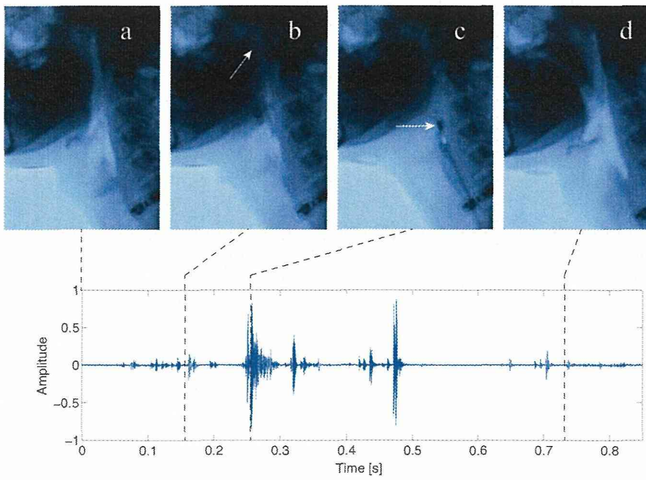


Fig. 2. Comparison of the swallowing sound with the corresponding videofluoroscopic images.

swallow test, Coloured water test, Cervical auscultation of swallowing and Swallowing provocation test (swallowing reflex test) are some of the screening test that can be performed without the need of any special tools [8]. However, these screening tests too need to be carried out by trained staff and the evaluations are often non-quantifiable. In order to address these limitations we developed the Swallowscope that can continuously monitor swallowing activities and provide quantitative statistics on swallowing ability for assisting dysphagia screening.

The Swallowscope is a wearable device, and uses the swallowing sound to evaluate swallowing ability (Fig. 1). Based on $m$Health, it can be used conveniently during activities of daily life. Earlier we reported the specific features of sound produced during swallowing [9]. This paper describes the development of a feasible real-time algorithm and evaluates the Swallowscope by using in RSST-based screening.

## II. METHODOLOGY

Since aspiration is not likely to happen with every swallow, especially in patients with mild dysphagia, continuous monitoring has a better chance of capturing aspirations or risky swallow patterns. As swallowing sound can be captured continuously and during activities of daily life (ADL) with minimal intervention, it is an ideal approach to monitor swallowing activities. The Swallowscope we conceptualized in Fig. 1 is a portable wearable system that can be used easily during ADL for the real-time assessment of swallowing function. The examiner could use the screen of the smartphone for a detailed description of swallowing activities, and a caregiver could use the visualizations at the neck-wear for a simpler real-time assessment of each swallow such as whether the swallowing happened normally or whether there has been signs of aspiration. By using a smartphone for processing the data, we wanted to make the technology widely available and more affordable. Furthermore, by automatically uploading/backing-up the swallowing related raw-data to a remote server, it is possible to re-evaluate the whole

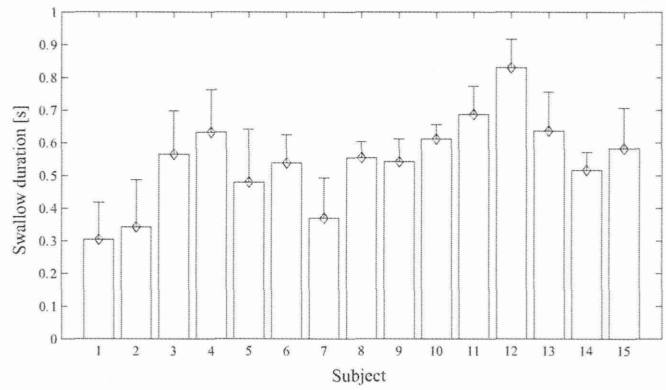


Fig. 3. Variation of average length of a swallow during RSST

swallowing process as well as perform more detailed analysis on a pc at a latter time by using more demanding algorithms.

By comparing the audio wave profile during swallowing with the corresponding VFSS images, Morinière et.al have reported on the origin of the sound components [10]. By carefully synchronizing videofluoroscopic (VF) images with the audio we analyzed the event based temporal and frequency characteristics of the audio waveform. In order to synchronize VF images with audio, we triggered an audio signal within the VF environment, and time-wise aligned the VF images with audio waveform, eliminating any delays associated with the VF and audio data capturing systems. Fig. 2 shows a comparison of audio waveform with VF images (the data, which corresponds to a dysphagia patient is fairly close to a healthy-swallow audio pattern). As it can be seen from Fig. 2, the sound components produced during swallowing are related to a chronological series of anatomical activities: (a) resting state, (b) movement of the soft palate and the larynx while bolus moving into the pharynx, (c) movement of the bolus into the esophagus, and (d) returning of the larynx back to the resting position. Acoustic event related to (c) was the most prominent and present in 100% of the healthy samples we examined (8 healthy and 62 dysphagic subjects), however, events (b) and/or (d) were not observed in some of the samples.

### *A. Selection of parameters for the swallow activity recognition algorithm*

In this study, we focused on the swallowing activities related to the RSST. The RSST is a simple test developed by Oguchi et.al for the screening for functional dysphagia and has a sensitivity of 98% for the aspiration [11]. RSST counts the number of repetitive dry swallows within a period of 30 s, and if the count is less than 3, then the subject is considered to have a stronger possibility of having dysphagia. In RSST, the number of swallows is counted by the movement of laryngeal elevation, either visually or by palpating, which is difficult to perform without proper training and experience. We also believe the variation of length of swallows and the duration between swallows could provide further insights into the swallowing ability, and the simple swallow count is not the only parameter that can evaluate swallowing ability.

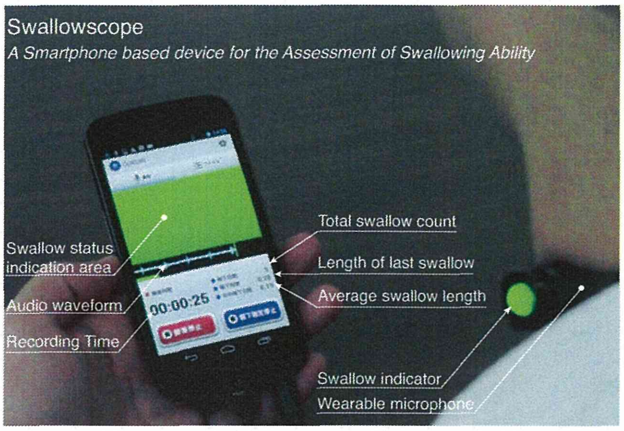


Fig. 4. Overview of the Swallowscope, showing the indicator side of the neck-worn microphone and the display of the smartphone application

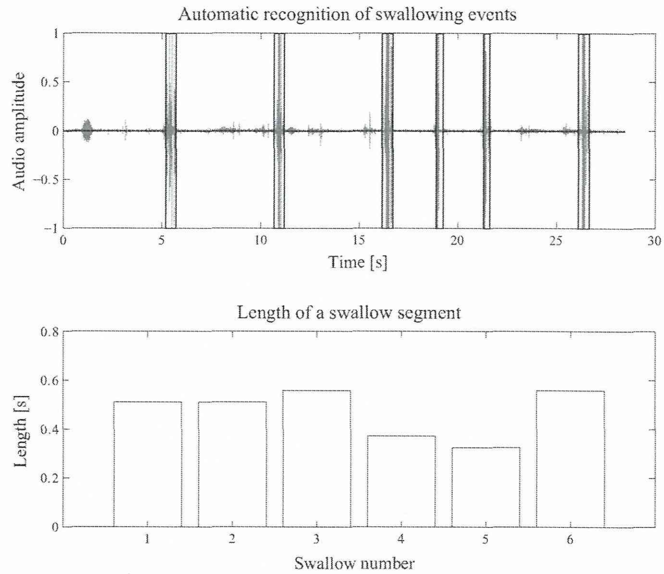


Fig. 5. Real-time recognition of swallowing activities during RSST

In order to find necessary parameters for the swallow activity detection algorithm, we performed RSST on 15 subjects; and to analyse the data for feature extraction, we asked a speech therapist and an experience swallowing sound coder to tag the starting and end points of each swallow during RSST. From the data, we noticed significant variations in lengths of swallow segments from person to person (p-value$<0.001$), but less variations for the same person. Fig. 3 shows the variation of average swallow lengths of the 15 subjects. The test yielded an average swallowing time of 0.51 s (S.D = 0.16).

*B. Real-time processing of swallowing sound*

The swallowing sound processing consists of 3 phases: preliminary detection of swallow sound pattern, elimination of cough and vocalizations and final detection. In the smartphone based algorithm, audio is captured as 16-bit pcm (Pulse-code modulation) at a rate of 11025 Hz and processed after acquiring into a 512-size buffer.

In the preliminary detection, we capture the sound profiles that are bounded by silent segments longer than 139 ms (3 buffers) to a sound segment. Here, an acquired audio data buffer is considered silent if the maximum value is less than a predefined threshold. As it can be seen from Fig. 2, typically the audio produced at different anatomical levels are separated by silent periods that are shorter than 3-buffers. As a result, a silent period within an audio segment indicates a switch in the anatomical region. After selecting the preliminary audio segment, a continuous wavelet transformation is performed and the amplitudes of the scale 19 is compared against a predefined threshold to detect cough and sections of vocalization. Finally, the audio segment is tested for: (a) total length, which should be between 232 ms (5-buffers) and 700 ms (15-buffers), and (b) number of sections (detected anatomical regions), which should be between 2 and 4. If all the above conditions are satisfied, the audio segment is considered a proper swallow.

Fig. 4 shows the smartphone-based Swallowscope. The swallowing sound is captured from the neck-worn wired contact microphone and the real-time processing outcome is displayed on the screen. The microphone was placed approximately around the c5 level of the cervical spine; however, since the features used for swallow recognition were less sensitive to the microphone location [9], it was often worn by the subjects, themselves. The display statistics consists of the number of swallows recognized, the total time taken for the last recognized sallow and the average time taken for a swallow. The recognition outcome is shown both at the indication area of the smartphone and with the indicating full-colour-LED of the neck-worn microphone with 3 different colours: blue for no swallow or stand-by, green for proper swallow and red for cough.

## III. EVALUATION AND RESULTS

In order to evaluate the accuracy of automatic recognition, we used the Swallowscope to evaluate RSST activity of 8 subjects while simultaneously performing VF, whereas the VF images were used as the ground-truth to calculate recognition accuracy. Fig. 5 shows the results of one of the RSST, reproduced with the exact offline version of the real-time algorithm. In this instance, the Swallowscope recognized all the swallowing events accurately.

Fig. 6 shows the precision (fraction of retrieved instances that are relevant) and recall (fraction of relevant instances that are retrieved) of automatic recognition estimated according to the ground-truth obtained from VF evidence. Overall, the automatic swallow recognition algorithm achieved a precision of 83.7% and a recall of 93.9%.

Due to the quantitative nature of evaluation, it is possible to use the Swallowscope to obtain more information about the swallowing process, and Fig. 7 compares the timing characteristics of swallows during RSST of a healthy subject (male, 35) and a dysphagic subject (female, 60's). The healthy subject managed 15 number of swallows within the period of 30 s whereas the dysphagic subject could manage 2 swallows only.

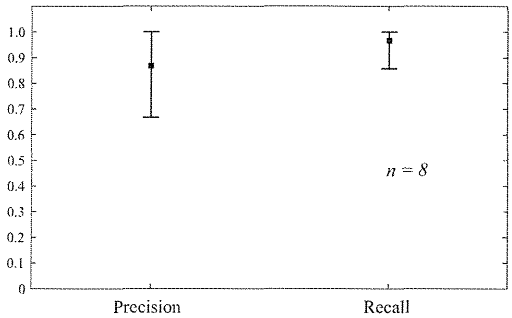


Fig. 6. VFSS evidence-based accuracy for the automatic detection of swallowing activities during RSST

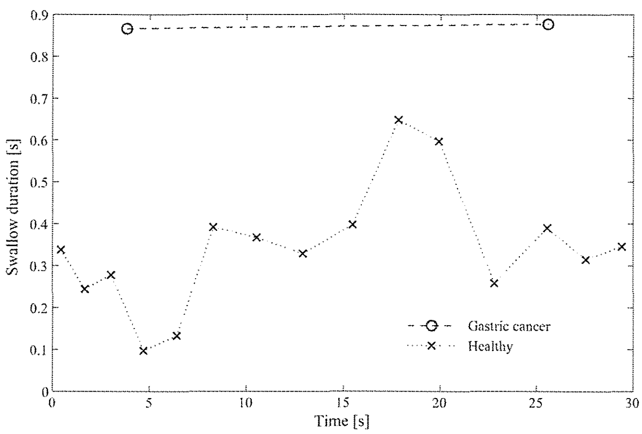


Fig. 7. Comparison of RSST timing characteristics of a healthy subject and a dysphagic subject due to gastric carcinoma

## IV. DISCUSSION

Swallowscope is the smartphone based device we developed to continuously monitor swallowing activities and assess the swallowing ability. In the current stage where we focused more on the RSST, we wanted to increase the recall: the true positive rate, to make sure the Swallowscope's categorization of not risky could be accepted with high confidence. The standard screening techniques used to assess swallowing ability have 2 main limitations: the person who conducts the screening test needs to be an expert to identify various outcomes of the test including correctly recognizing swallows and the outcome of the tests are subjected to qualitative interpretation of the examiner. The Swallowscope on the other hand does not require any special knowledge nor training and the results it produce are quantitative. As a result, they are reproducible and comparable. Our current algorithm for instance is capable of recognizing precise temporal characteristics of swallowing activities. It can accurately determine when did the swallow has occurred and how long the swallow was. As a result, it could be possible to define more definitive parameters to evaluate swallowing ability. As seen in Fig 5, we could analyse the progress of swallowing activities, whether the subject is slowing down by using gap between swallows, and whether the time for a swallow is increasing from the swallow length information. These parameters could indicate whether the swallowing function of the subject is getting unusually tired. As it can be seen from Fig. 7, healthy subject, while managing 15 swallows, did not have any problem maintaining the swallowing rate. And the swallows too took much shorter time to complete, indicating much stronger and quicker swallows. Just as coughing indicates possible aspiration, ability to cough properly is important to make sure that the person can cough any aspirated food particles out. Healthcare workers often would like to know it before feeding someone who is in a risk of aspirating, and we could use the cough detection to determine whether their coughs are strong enough to serve this purpose.

## V. CONCLUSIONS AND FUTUREWORKS

We developed a smartphone-based device that can analyse swallowing sounds in real-time and generate quantitative results to assist the bedside screening for swallowing ability. We achieved a very high value for recall, indicating the Swallowscope's categorization of not risky could be accepted with confidence. We further demonstrated the ability to generate quantitative measures about the swallowing ability, and this could help to produce more reliable screening methods.

We are currently working on compiling a large database of healthy and dysphagic swallowing patterns and plan to improve pattern-recognition algorithm to increase the screening accuracy and robustness as well as to directly detect dysphagic swallowing patterns. We also believe it is possible to describe swallowing pressure from the swallowing sound and currently conducting a study that combines swallowing sound, VFSS and high-resolution manometry (HRM).

## REFERENCES


[1] E. T. Cunningham Jr and B. Jones, *Normal and Abnormal Swallowing: Imaging in Diagnosis and Therapy*. Springer, 2003, ch. 2.

[2] "Vital statistics in japan-the latest trends," Ministry of Health, Labour and Welfare, Tech. Rep., 2011. [Online]. Available: http://www.mhlw.go.jp/english/database/report.html

[3] O. Ekberg, S. Hamdy, V. Woisard, A. Wuttge-Hannig, and P. Ortega, "Social and psychological burden of dysphagia: Its impact on diagnosis and treatment," *Dysphagia*, vol. 17, no. 2, pp. 139–146, 2002.

[4] P. E. Marik and D. Kaplan, "Aspiration pneumonia and dysphagia in the elderly," *CHEST Journal*, vol. 124, no. 1, pp. 328–336, 2003.

[5] V. Tentzeris, B. Lake, T. Cherian, J. Milligan, and A. Sigurdsson, "Poor awareness of symptoms of oesophageal cancer," *Interactive CardioVascular and Thoracic Surgery*, vol. 12, no. 1, pp. 32–34, 2011.

[6] B. Martin-Harris and B. Jones, "The Videofluorographic Swallowing Study," *Physical Medicine and Rehabilitation Clinics of North America*, vol. 19, no. 4, pp. 769–785, 2008.

[7] S. B. Leder, D. M. Suiter, H. L. Warner, L. M. Acton, and B. A. Swainson, "Success of recommending oral diets in acute stroke patients based on passing a 90-cc water swallow challenge protocol," *Topics in Stroke Rehabilitation*, vol. 19, no. 1, pp. 40–44, 2012.

[8] S. Horiguchi and Y. Suzuki, "Screening tests in evaluating swallowing function," *JMAJ*, vol. 54, no. 1, pp. 31–34, 2011.

[9] M. Nagae and K. Suzuki, "A neck mounted interface for sensing the swallowing activity based on swallowing sound," in *Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE*, 2011, pp. 5224–5227.

[10] S. Morinière, M. Boiron, D. Alison, P. Makris, and P. Beutter, "Origin of the sound components during pharyngeal swallowing in normal subjects," *Dysphagia*, vol. 23, no. 3, pp. 267–273, 2008.

[11] K. Oguchi, E. Saitoh, M. Mizono, M. Baba, M. Okui, and M. Suzuki, "The Repetitive Saliva Swallowing Test RSST as a Screening Test of Functional Dysphagia. (1). Normal Values of RSST," *The Japanese Journal of Rehabilitation Medicine*, pp. 375–382, 2000, In Japanese.