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Development of a Web Application That Evaluates Suture Performance in Off-the-Job Training

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Objective: To create a web application that can evaluate suture performance and assess its quality.
Material and Methods: We developed the web application using a few cloud computing systems, servers, database, and computing languages. We used 20 anastomosed graft samples for optimizing the application. The images of the anastomosed grafts were captured two-dimensionally. Five vascular surgeons utilized the application to compute the objective score and rank the score of the anastomoses subjectively.
Results: Steps for using the application include uploading a two-dimensional image of sutures, tracing the stitch line manually, and pushing the button to have the score displayed. After using this system for more than 1,000 times without server issues or failures, we confirmed its stability and easy accessibility. The system calculated the score within several seconds. The score of the three factors (bite, pitch, and skewness of angle) ranged from 0.25 to 0.76. The error range of the application was acceptable. The interclass correlation coefficient (ICC (2,1)) of the three factors was 0.92.
Conclusion: The quality of the application was acceptable considering the low range of interoperator variations in the scores.

Keywords: off-the-job training, suture, evaluation, web application

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Introduction

Surgical skills and methods were usually passed down from experienced surgeons to beginners in the so-called apprentice system. In this period of information overload, it is essential to get an accurate picture of the training systems in place to assess their effectiveness. However, most reports examining training systems use the subjective scores assigned by supervising surgeons.[1–4] Time taken for procedures has been preferably used in literatures as a gold standard of objective evaluation.[5–7] Although a few studies adopted the thread tension as the objective evaluating factor,[8,9] it cannot necessarily demonstrate the whole procedural achievement.

In our previous report which demonstrated the original homebuilt off-the-job training (Off JT) system, we used the operative time and operative performance rating system (OPRS) to calculate the procedural performance.[10] In addition, we also evaluated the anastomosed graft with balance of sutured thread: bite and pitch. These objective factors were derived from the "segmentation" process, which clarify the thread line from the pictures of the anastomoses. However, this process was time-consuming. Therefore, we developed a web application that could function as a substitute for the segmentation process of suture performance evaluation and evaluate its quality.

Materials and Methods

System overview

The workflow of application development is depicted in **Fig. 1**. We used AngularDart (https://angulardart.dev/) as client-side framework for creating the application, which is required to be hosted in some servers. We considered the Firebase (https://firebase.google.com/) and Google Cloud Platform (https://cloud.google.com/) to be the most suitable server and connected cloud computing system to perform calculations. We uploaded the image of the sutures and manually traced the lines in the AngularDart at first and submitted the results to Firebase. The segmentation

process and calculation were conducted on the Google Cloud Platform and then pushed to the database in the Firebase. The data were automatically displayed on the client application.

To perform segmentation of the suture line images, we used the programming language, Python 3.7 (https://www.python.org/), and the computing libraries, NumPy (https://numpy.org/) and SciPy (https://www.scipy.org/), and the image processing library, OpenCV 4.1.0 Python bindings (https://opencv.org/). The suture lines were segmented by using OpenCV, and the scores were computed using NumPy and SciPy.

Score of sutures

For evaluating suture performance (balance of the suture), we used two factors adopted in our previous study: the bite (the length of a stitch across the graft/tube) and pitch (the interval between stitches).[10] The balance was evaluated with the coefficient of variation (CV) as shown previously.[10]

In addition, we adopted another factor—skewness—to evaluate the balance of the angle among stitches, especially in curved suture lines of side-to-end anastomoses. The skewness was calculated by using the circular statistics as defined by Pewsey.[11] (**Fig. 2**). Lower scores suggest excellent arrangement of sutures. We defined the total score of the three factors as the norm of the vectors of the CV of the bite, CV of the pitch, and skewness of angle.

Evaluation of the system

Five vascular surgeons (KH, TA, TI, KY, TT) used this system with ten end-to-end and ten end-to-side anastomosed graft samples to investigate the interobserver bias. Moreover, they evaluated the anastomosis itself with the subjective scores that we set: 1 (beginner) to 10 (expert) (**Fig. 3**). We analyzed the correlation among the scores of the three factors.

We used R 3.6.1 (https://www.r-project.org/) and IRR packages (https://cran.r-project.org/web/packages/irr/index.html) for statistical analysis.

The study protocol was approved by the Institutional Research Ethics Committee of the University of Tokyo Hospital (No. 11567).

Results

The steps of using this system are illustrated in **Fig. 4**. First, log in with Google account. Second, upload the file with suture images by clicking the button on the left side (1). Third, click the Trace button (2) and trace the stitch line. If you fail to trace the line, use the Erase or Clear button (3) and (4). Finally, click the Upload button, and the score will be displayed on the right side (**Fig. 4**).

After using this application more than 1,000 times without any server problems or crashes, we confirmed the application's stability and ease of use; moreover, most often, the application calculated the scores within a few seconds. The source codes were published in GitHub (https://github.com/studiome/suture-eval-web-app) with MIT License. A limited (less detailed) demonstration video was uploaded to YouTube (https://www.youtube.com/watch?v=BSyb2tkZMp4).

The score of the three factors (bite, pitch, and skewness
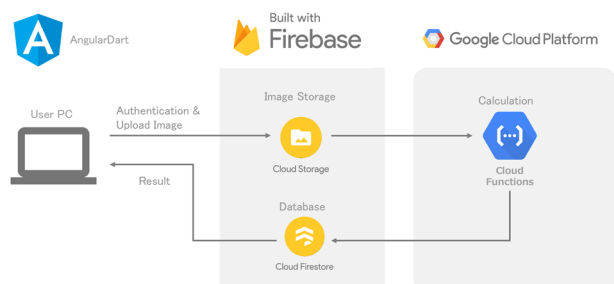

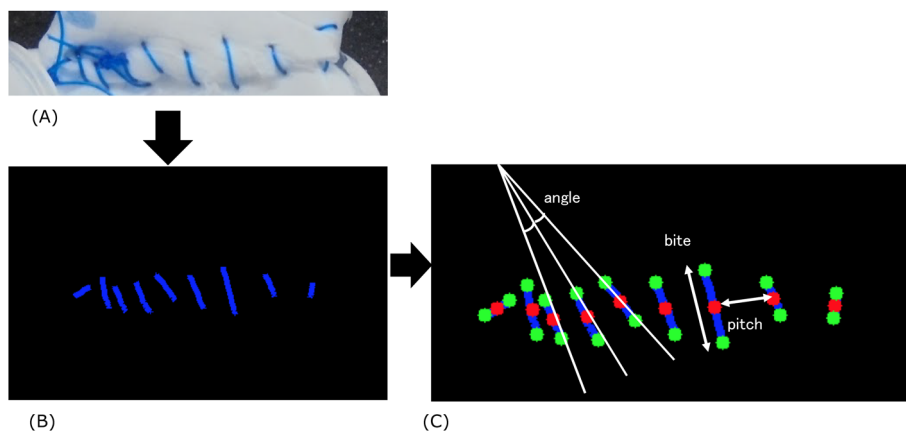**Fig. 1** Web application development: an overview.

Fig. 2 (**A**) Image of a suture. (**B**) Segmentation of the suture line. (**C**) Definition of the bite, pitch, and skewness.

of angle) ranged from 0.25 to 0.76. The error range of the application was acceptable. The interclass correlation coefficient (ICC) (2,1) of the three factors was 0.92 (**Fig. 5**).

The range of subjective scores among five trainers was 2–10. The ICC (2,1) was 0.51. The correlation between the score of the three factors and subjective score was 0.03, which was not significant.

Discussion

In 2017, the Japanese Board of Cardiovascular Surgery recommended 30 h of Off JT for new cardiovascular specialist applicants. Since then, Off JT has been increasingly used in different cardiovascular workshops. However, the quality of the Off JT, including some expensive simulators and commercialized kits, has not been scientifically evaluated. We previously presented a simple and inexpensive Off JT system which could be settled and used by any institutes and surgeons. Moreover, we studied anastomotic performance under the system and revealed that procedure time, objective score for the skills, and anastomotic quality were considerably correlated.[10]

The system was practically used in the Distal Bypass Workshop (http://www.jsvs.org/ja/event/distal_bypass_workshop/) carried out by the Japanese Society for Vascular Surgery from 2017 to 2019. Our purpose for developing this application of "segmentation" was derived from the responses to questionnaires administered in the past workshops. A lot of surgeons wished for immediate feedback of their graft anastomosis performance. The application worked accurately in the most recent workshop held in June 2019, and the scores of approximately 100 anastomoses were calculated and analyzed until the closing ceremony. A questionnaire of the workshop revealed that real-time feedback of the procedures was extremely popular. Therefore, our tool will not only help improve surgical skill but also increase interest in surgery for young doctors.[12]

In our setting of suture performance evaluation, each anastomotic image was captured two-dimensionally; the resected anastomosis was placed and pushed between two acrylic transparent sheets wherein its picture was captured for evaluation (**Fig. 2**, upper image). However, the unidirectional images could not fully reflect the anastomotic performance, which is probably why the scores of subjective evaluation by supervising surgeons did not correlate with the scores of the objective factors. Our application should be considered as one of the tools to assess suture performance. Other evaluation methods such as those testing leakage from the anastomotic site or evaluating thread tension could be used in our newly developed Off JT system in the future.[8,13]

We added the skewness as a factor to complement the two factors, bite and pitch, which we think could not reflect the balance in the curved suture line. However, the variable range of skewness was revealed to be greater compared to those of bite and pitch. Also, the unit of skewness was not CV. We figured out the total score as the norm of vectors; however, this method should be further
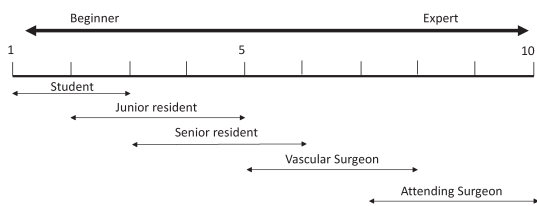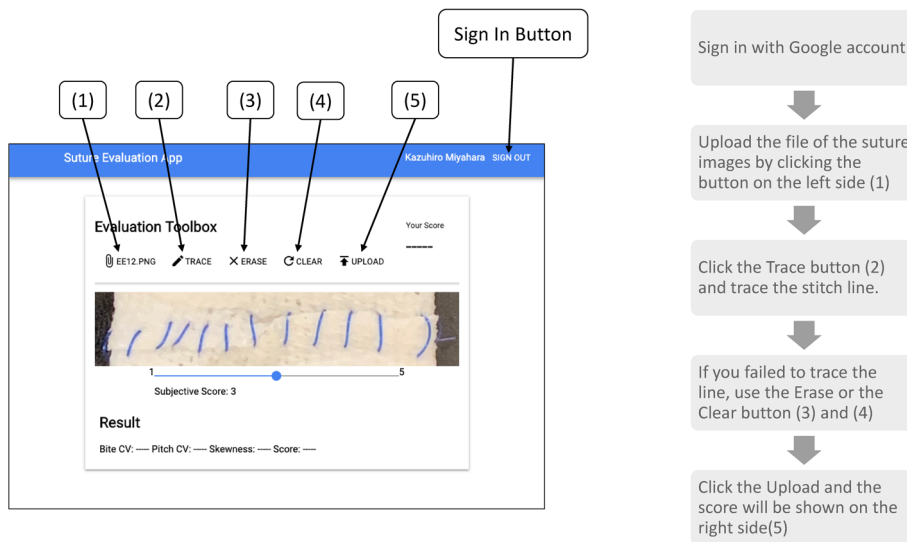
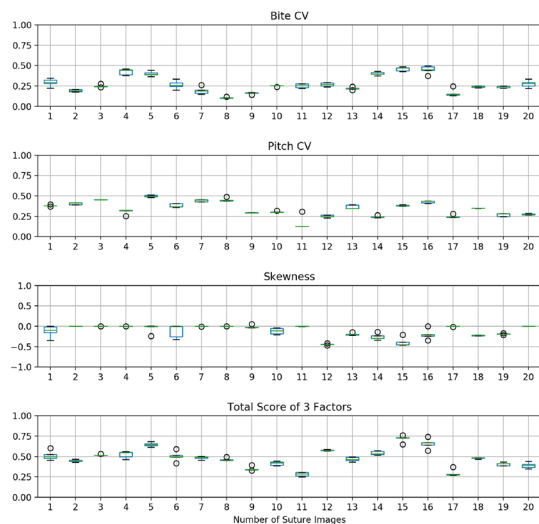**Fig. 3** Subjective score scale of sutures.

Fig. 4 Steps involved in using the web application.

Fig. 5 The scores of 20 anastomoses: bite, pitch, skewness, and total score.

optimized in the future.

There are various kinds of anastomoses and we introduced several ones in our training program. Gaber and Abdel-Wahed demonstrated the suture coding for every suture pattern as a novel educational method.[14] In the field of laparoscopic surgery, a marker was set as a target of the needle puncture site, which should be regarded as "coding."[15] Our application might be helpful for such coding.

Conclusion

We designed a web application which served as an alternative for the segmentation process to evaluate suture performance in the Off JT. We confirm that the quality of the application is acceptable because of its computing stability, low range of interoperator variations in the score, and short time required to compute scores.

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None.

Disclosure Statement

There is no conflict of interest to declare.

Author Contributions

Study conception: KM, KH
Data collection: TA, TI, KY, TT
Analysis: KH
Investigation: KH, TT
Writing: KM, KH
Critical review and revision: all authors
Final approval of the article: all authors
Accountability for all aspects of the work: all authors

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