Original Article

Impact of Breathing Control Training Program on sonographic quantification of abdominal vasculature

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ABSTRACT

الأهداف: مقارنة عوامل مسح الأوعية الدموية (قطر الوعاء، ذروة السرعة الانقباضية، السرعة الانبساطية النهائية، ومؤشر المقاومة) ووقت المسح قبل وبعد برنامج التدريب على التحكم في التنفس لأوعية البطن المختارة.

المنهجية: تعتبر هذه الدراسة قبلية وبعدية شبه تجريبية حيث صمم الباحثون برنامجًا تدريبيًا على التنفس يعطي المشاركين تعليمات من خلال مقطع فيديو يصف مناورات التنفس. تم جمع البيانات في مختبر الموجات فوق الصوتية / كلية الصحة وعلوم والتأهيل بجامعة الأميرة نورة بنت عبد الرحمن في الفترة من يناير 2023 إلى نوفمبر 2023. وشارك في الدراسة حوالي 49 متطوعًا من الجامعة. تم إجراء المسح مرتين للشريان الكلوي الأيمن، والشريان الأورطي البطني العلوي، والوريد الأجوف السفلي، والشريان المساريقي العلوي. تم قياس وقت المسح قبل وبعد البرنامج أيضًا. تم استخدام اختبار t لعينة مقترنة لمقارنة العوامل والوقت قبل وبعد البرنامج.

النتائج: كان للبرنامج تأثير كبير على العوامل التالية: ذروة السرعة الانقباضية للشريان الكلوي الأيمن (p=0.042)، ذروة السرعة الإنقباضية ومؤشر المقاومة في الشريان الأورطي البطني العلوي (p=0.014، p=0.014 على التوالي)، وقطري الشريان المساريقي العلوي والوريد الأجوف السفلي (p=0.010 ، p=0.020على التوالي) تم تقليل وقت المسح بشكل ملحوظ. (p<0.001)

الخلاصة: برنامج التدريب على التنفس يوفر الوقت ويحسن جودة القياس بالموجات فوق الصوتية. يجب على المستشفيات والمراكز الصحية أن تأخذ في الاعتبار أهمية برامج التدريب على التحكم في التنفس قبل إجراء فحص البطن.

Objectives: To compare vascular scanning parameters (vessel diameter, peak systolic velocity, end-diastolic velocity, and resistive index) and scanning time before and after breathing control training program for selected abdominal vessels.

Methods: This study was pre and post quasi-experimental. The researchers designed a breathing training program that gives participants instructions through a video describing breathing maneuvers. Data were collected at the ultrasound laboratory/College of Health and Rehabilitation Sciences in Princess Nourah bint Abdul Rahman University, Riyadh, Saudi Arabia from January 2023 to November 2023. About 49 volunteers at the university participated in the study. Scanning was performed two times for the right renal artery, upper abdominal aorta, inferior vena cava, and superior mesenteric artery. Scanning time was measured before and after the program as well. A paired sample t-test was used to compare the parameters means and time before and after the program.

Results: The program had a significant effect on the following parameters: right renal artery peak systolic velocity (p=0.042), upper abdominal aortic peak systolic velocity, and resistive index (p=0.014, p=0.014 respectively), superior mesenteric artery and inferior vena cava diameters (p=0.010 and p=0.020). The scanning time was reduced significantly (p<0.001).

Conclusion: The breathing training program saves time and improves ultrasound measurement quality. Hospitals and health centers should consider the importance of breathing control training programs before abdominal scanning.

Keywords: breathing exercises, quantification, vasculature, scanning, ultrasound

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Sonographers face challenges in abdominal scanning of the structures, especially abdominal vessels, because of cardiac pulsation, bowel gas, and respiratory movement.[1] During abdominal sonographic scanning, breathing motion can significantly distort abdominal organs.[2] It causes artifacts and affects spatial resolution.[3] Therefore, for vascular scanning, the patient may be instructed to hold breathing or breathe gently.[1]

Different studies approved the effect of breathing maneuvers on sonographic measurements. Different studies were carried out to assess the best respiratory maneuvers for the best views and measurements. For example, during the scanning of the aorta and inferior vena cava (IVC), the patient is instructed to respirate quietly and hold breathing for a short time during spectral tracing.[1] For those who are practicing abdominal breathing, the collapsibility of IVC is the best during slow breathing.[4]) The renal artery spectral measurements, peak systolic velocity (PSV) and end-diastolic velocity (EDV), reach their maximum values during deep inspiration.[5] Mesenteric Doppler ultrasonography should be conducted during expiration to avoid the underestimation of artery stenosis.[6]

Respiratory maneuvers do not affect only the scanning of vessels but also abdominal organs such as the liver, the spleen, the pancreas, and the kidneys.[7-10]

However, patient understanding of the breathing technique is challenging, for example some patients do Valsalva maneuvers instead of breath holding, hindering the diagnostic accuracy of the sonographic examination and leading to spending more time explaining the procedure for the patients.

Videos are highly effective for education and training, as they facilitate better information retention compared to verbal presentations alone. Incorporating on-screen text and graphics enhances comprehension, and the dynamic nature of videos makes learning more enjoyable, thus improving learner engagement.[11] In this study, we hypothesized that implementing video based breathing traning program will improve the quality of sonogragraphic assessment of abdominal vasculature by improving patient understanding of the breathing technique. Thus, the aim of this research is to assess the measurements of abdominal vasculature in sonographic assessment before and after the video based breathing training program.

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Methods. This study was a pre and post quasi-experimental study when the volunteer was assessed twice, before and after the training program. This study was approved by the research center at Princess Nourah bint Abdul Rahman University (PNU), Riyadh Saudi Arabia (IRB No. 22-1009). After the procedure was explained, the participant signed a consent form. The data were used only for study purposes, without individual details identifying the participant.

Data were collected at the ultrasound laboratory/ College of Health and Rehabilitation Sciences in PNU from January 2023 to November 2023. The study included 49 healthy young female volunteers between 18 and 25 years of age. Any female with vascular disease, chronic disease, or irritable bowel syndrome (IBS) was excluded. The sonographic scanning was performed using a Philips iU22 Ultrasound Machine and convex probe (2-5 MHz).

The first step was designing a breathing maneuver training program. The program gives participants instructions through a video describing breathing maneuvers in Arabic, which is the mother language of the participants, and there is a translation into English at the bottom of the screen. Breathing maneuvers included quiet breathing, deep inspiration and hold, and expiration and hold.

Training steps for quiet breathing (eupnea):[12] i) Lie down on your bed and relax your self. ii) Breathe in a relaxed manner through your nose with one hand on the top of your abdomen and the other on the top of your chest, and you will notice your hand rising. A good breath should take 3 seconds at least to complete. i) Breathe out through your mouth. ii) Repeat this process for 5 to 10 minutes.

Deep inspiration belly breathing (diaphragmic) and hold steps:[13,14] i) Sit back or lie down and relax your shoulders. ii) Take a normal breath. iii) Breathe slowly through your nose, allowing your chest and lower belly to rise as you fill your lungs. i) Let your abdomen expand fully and hold it as long as possible. ii) Now breathe out slowly through your mouth or your nose.

Expiration and hold:[15] After deep inspiration, breathe out slowly through your mouth or nose and hold your breathing as long as possible.

Manovers should be repeated 5 times per day. 6:00 am, 12:00 pm, 3:00 pm, 7:00 pm, 9:00 pm and lasts for 10 to 15 minutes.

The second step was explaining the procedure to the participant. Ultrasound scanning for structures was performed 2 times before and after the training program. Four abdominal vessels were selected to be scanned. Scanning of these vessels demonstrates the effect of different breathing maneuvers. These vessels are main right renal artery (RRA), upper abdominal aorta (UAA), IVC, and superior mesenteric artery (SMA).

To eliminate the interoperator variability, the same trained researcher performed the scanning before and after the training program under the supervision of a specialist. Volunteers were instructed to fast for 6-8 hours. Scanning was performed when the volunteer was in a supine position. The first scanning for the patient and breathing maneuver instructions were given as usual. Then, the volunteer was given the program, and the same scan was repeated after five days.

Sonographic scanning and standard measurements RRA. Scanning was performed for scanning RRA according to AIUM's guidelines.[16] Measurements were taken with deep inspiration and hold. Evaluation should always start with B-mode grayscale imaging to measure the diameter (5 to 6 mm).[17] Then, spectral Doppler was applied for peak systolic velocity (PSV) (80-150 cm/s), EDV (20-50 cm/s), and resistance index (RI) (0.5-0.7).[18]

Abdominal aorta and IVC. Scanning for UAA and IVC was performed according to the guidelines of AIUM's guidelines.[19] When the probe was in a longitudinal orientation high in the epigastrium, using the liver as a sonographic window, UAA was identified on the volunteer's left and IVC on the volunteer's right anterior to a vertebral body. Scanning was performed with quiet respiration. The following parameters were obtained UAA diameter (<3.0 cm), PSV (50.7-152.9 cm/sec), End diastolic velocity (EDV) (0-39.4), and resistance index (RI) (0.72-1.0).[20,21] IVC diameters 12 to 17 mm.[22] Figures 1&2 demonstrate the effect of the training program on the measurements of UAA and IVC.

Superior mesenteric artery. From the long axis of the proximal aorta, the celiac and superior mesenteric arteries were visualized arising from the anterior wall of the aorta. The same parameters were assessed when the patient expired: diameter (5.7–7.3 mm), PSV (77.3-247.2 cm/s), EDV (11.4-55.4 cm/s), and RI (0.67-0.94).[21,23]

A designed data collection sheet containing all study variables was used. These variables are vessel diameter, PSV, EDV and RI for RRA, UAA and SMA, and vessel diameter for IVC.

Statistical analysis. The data were analyzed using descriptive statistics (mean ± standard deviation [SD]) and a statistical test, paired-sample T-test, to compare between 2 means. The Statistical Analysis for Social Sciences for Windows, version 28 (IBM Corp., Armonk, N.Y., USA) was used for analysis.

Results. The study was conducted on 49 young female volunteers between 18 and 22 years old. Their body mass index (BMI) was between 17.2 and 28.3. Table 1 demonstrates the basic characteristics of the study population.

Table 2 shows mean ± standard deviations (SD) for vessel measurements. The paired samples t-test was used to compare the mean diameter, Doppler parameters and

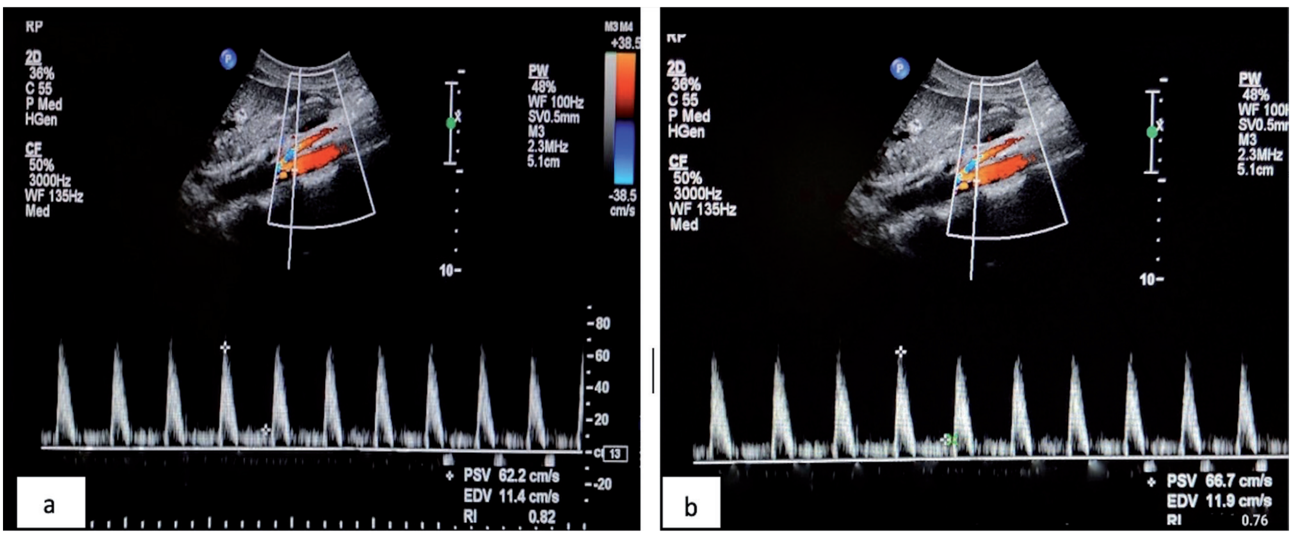

Figure 1 - Upper abdominal aorta Doppler measurements. **a**) peak systolic velocity (PSV), end diastolic velocity (EDV), and resistance index (RI) before the breathing training program. **b**) PSV, EDV, and RI after the breathing training program

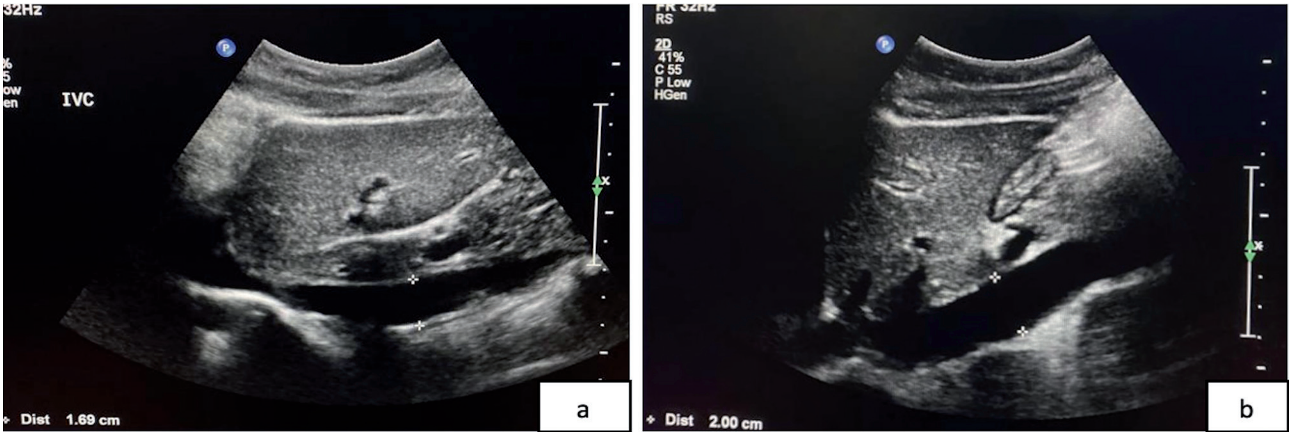

Figure 2 - Inferior vena cava diameter. **a**) Diameter before breathing training program. **b**) Diameter after breathing training program

Table 1 - Basic characteristics of the study population (N=49).

Variable	Mean ±SD	Minimum	Maximum
Age (years)	21.3721 ± 0.90035	19	24
BMI (kg/m^2)	21.4535 ± 3.39282	17.20	28.30

BMI: body mass index, SD: standard deviation

Table 2 - Comparison of means between vessels measurements pre and post-training program using paired sample t-test (N=49).

Measurement	Pre-training Program Mean ±SD	Post-training Program Mean ±SD	Mean Δ	Lower limit	Upper limit	T	Sig. (2-tailed)
RRA diameter	0.38 ± 0.11	0.36 ± 0.091	6.39	-.011	0.052	1.262	.213
RRA PSV	57.12 ± 18.17	50.72 ± 13.01	6.09	0.24	12.54	2.092	.042*
RRA EDV	23.96 ± 24.64	17.87 ± 4.34	.0008	-1.19	13.38	1.680	.099
RRA RI	0.64 ± 0.07	0.64 ± 0.07	6.39	-.022	0.024	.071	.944
UAA diameter	1.30 ± 0.19	1.38 ± 0.27	-0.071	-0.15	0.009	-1.781	.081
UAA PSV	75.07 ± 28.74	64.56± 17.71	10.51	2.26	18.78	2.560	.014*
UAA EDV	12.64 ± 5.63	12.08± 3.46	0.55	-1.12	2.23	.663	.510
UAA RI	0.83 ± 0.042	0.80 ± 0.068	0.03	0.006	.050	2.563	.014*
IVC Diameter	1.69 ± 0.30	1.82 ± 0.41	-0.13	-0.23	-.022	-2.410	.020*
SMA diameter	0.56± 0.12	0.52 ± 0.11	0.047	0.012	0.08	2.694	.010*
SMA PSV	97.73 ± 51.21	82.18 ± 51.21	15.54	-0.079	31.17	2.000	.051
SMA EDV	14.74± 8.89	13.65 ± 6.11	1.09	-1.79	3.98	.760	.451
SMA RI	0.85 ± 0.060	0.83 ± 0.07	0.018	-0.002	0.039	1.840	.072
Time	19.96 ± 9.73	11.16 ± 2.62	12.80	10.05	15.54	6.060	.000*

*Difference is significant. RRA: right renal artery, UAA: upper abdominal aorta, IVC: Inferior Vena Cava, SMA: superior mesenteric artery

time before and after the training program. The mean RRA PSV, UAA PSV, UAA RI, and SMA diameter were considerably lower than the value before the training program. The *p*-value for the paired samples t-test was less than 0.05. Inferior vena cavadiameter and scanning time show considerable differences ($p<0.05$). Values were greater after the training program as it is seen in Table 2.

Discussion. Regular breathing practice can assist the lungs with collected air, expand oxygen ranges and get the diaphragm to return to its job of assisting in breathing.[13] In clinical psychology, proper breathing conveys the proper amount of oxygen and allows the best carbon dioxide exchange, which plays a role in relieving anxiety and panic attacks.[24,25]

Sonographers conducting abdominal sonographic procedures for hospital patients discover that despite breathing exercises' role and their benefits, many people do not know different breathing maneuvers, especially deep belly breathing. Therfore, this study proposed a video based breathing control training program to demonstrate the breathing maneuver.

The breathing training program yielded a significant reduction in the peak systolic velocity of both the upper abdominal aorta and the right renal artery emphasizing on the role of breathing maneuvers in modifying this parameter. Consistently, a recent study by Zhang et al[26] reported similar findings.

These findings indicates a potential impact of breathing maneuvers in the diagnosis of vascular diseases such as renal artery stenosis which relay on parameters such as PSV and RI.[27]

The effect of the program on diameter is seen in IVC and SMA. This emphasizes that breathing technique has an impoact on the collapsibility of the IVC as stated by Caplan et al,[28] thus can influence the accuracy of using the collabsibility of the IVC to predict fluid responsiveness.

In this study, insignificant differences between pre and post-program parameters could be related to the inability to measure the diameter at the same point as in pre-training programs, especially the small diameter vessels like RRA. Doppler accuracy for SMA could be limited due to the functional status of the bowel, medication, emotional and physical status, and several other factors. However, these insignificant results limit the ability to accept the study hypothesis of utilizing video based training program to improve the sonographic examination. Despite that, video based training programs showed effectiveness in many clinical contexts, such as improving patient's knowledge in clinical settings and reducing anxiety and the sense of unfamiliarity that challenges the diagnostic procedures.[29,30]

Reduced scanning time is an important goal in medical imaging to improve efficiency, patient comfort, and overall workflow. In this study, the training breathing program allowed us to reduce scan times. The time before the training program was longer than the time after. Meantime dropped from 19.96 minutes to 11.1633 minutes (p<0.001). According to this, a video-based breathing training program could be useful in enabling medical professionals to conduct more examinations in a given amount of time without sacrificing quality.

The present study showed that video based breathing training program effectively reduced the examination time without significant impact on the mesurments. However, it is important to state that due to the limited recruited volunteers, successful utilization of a randomized control trial design was challenging, and restricted the utilization of a randomized controlled study design. Therefore, a quasi-experimental design was used and the sample size was conveniently determined This limitation limits the generalizability of the findings.

In conclusion, the training program helps healthcare practitioners optimize sonographic scanning processes, lowering examination times with no significant change in the diagnostic imaging quality. This provides an evidence for implementing video based training in clinical practice, for example, it can be implemented in busy clinics to reduce the examination time and enhance the efficiency of the clinic overall.

Future studies on the effectiveness of video based breathing training programs should take this study limitation into consideration; utilizing a randomized controlled trial design and including a larger sample size, for example, a multicenter study will provide more evidence and enhance the generalizability of the findings.

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