



Effectiveness of, and Satisfaction with, a Microsurgical Testicular Sperm Extraction Knowledge and Skills Masterclass for a World-Wide Audience

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Purpose: This is the first study to assess the impact of an online microsurgical testicular sperm extraction (mTESE) masterclass. We: 1) describe the masterclass's scientific content; 2) appraise the participants' acquisition of knowledge; 3) gauge whether the extent of improvement of the participants' knowledge/skills was influenced by demographic/professional attributes; and 4) evaluate the participants' satisfaction.

Materials and Methods: This masterclass comprised five didactic lectures followed by 4 case discussions. Online surveys assessed the above objectives using a baseline questionnaire including demographics and past mTESE experience/training, a 24-question pre- and post-quiz, and a satisfaction questionnaire.

Results: Participants were between 20–70 years old, with 80.37% males, mainly from Asia, Africa, and Europe, from clinical backgrounds (69.3%), and in public practice (64.4%). Half the sample reported no past mTESE training and very low skills, ≈60% wanted considerably more training, and 50% felt that good training was not readily available. Satisfaction was 98% to >99%. Pre- and post-quiz comparisons confirmed remarkable improvements in knowledge/skills, exhibiting five striking characteristics. Improvements were a) Broad *i.e.*, across 19 of the 24 mTESE questions; b) Deep, of magnitude, as pre-/post-quiz scores improved from mean 13.71±4.13 to 17.06±4.73; c) Highly significant, consistently with p-values <0.001; d) Inclusive *i.e.*, all participants enhanced their mTESE knowledge/skills regardless of demographic/professional attributes; and, e) Differential, *e.g.*, non-clinical/clinical participants improved, but the former improved relatively significantly more, those with ≤5-year experience improved significantly more than those with >5-year, those in public practice significantly more than private practice participants, and those with lower self-rating in performing mTESE significantly more than those with higher self-rating.

Conclusions: The masterclass was successful with very high satisfaction levels, and markedly improved mTESE knowledge/skills among the participants. Global Andrology Forum's model can be adopted by organizations with similar goals. Future research needs to evaluate such training to develop a practically non-existent evidence base.

Keywords: Azoospermia; Education, medical; Infertility; Male; Sperm retrieval

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INTRODUCTION

Non-obstructive azoospermia (NOA), affecting approximately 1% of men worldwide, is the most severe type of male infertility [1]. Although spermatozoa can be retrieved blindly using conventional testicular sperm extraction (TESE), it is only successful in a subset of these NOA patients [2]. Microsurgical testicular sperm extraction (mTESE), first introduced by Schlegel and Li in 1998 [3], is now widely used [4] and has been proposed as a clinically valuable salvage treatment option for men with previously failed TESE [5,6].

Successful mTESE requires a breadth of knowledge and skills for the appropriate evaluation of potential patients and successful execution of the mTESE procedure. These include understanding pertaining to presentation, history taking, physical examination, and selection and interpretation of investigations *e.g.*, semen analyses, testicular ultrasound, hormonal and genetic testing, and testicular histology [5,7,8]. Proper training in the procedure is also crucial as the surgeon's training and experience are key factors for successful sperm retrieval in mTESE, with substantial learning curves [9,10]. The required knowledge and skills can optimize patient selection to maximize the likelihood of successful sperm retrieval, currently between 25% and 60% [7,11]. In today's era of cost containment globally, given the high costs of the mTESE approach, the identification of candidates most likely to benefit from it is vital [8].

Further specialized knowledge is also required for patient-related and intra-operative predictors of mTESE success. A recent systematic review and meta-analysis as well as a range of studies found that age, testicular volume, follicle-stimulating hormone, luteinizing hormone, and testicular histopathology were valuable predictors of salvage mTESE extraction in NOA [12,13]. Furthermore, others proposed molecular biomarkers and noncoding RNAs in seminal plasma as predictors of sperm recovery [1,14]. Likewise, the characteristics of seminiferous tubules have been reported to predict mTESE outcomes among naive NOA patients [15]. Equally, advanced surgical and diagnostic techniques, varicocelectomy, and hormonal therapy interventions have been propositioned to increase retrieval [16,17].

Thus, training to improve the andrology team's knowledge and skills is imperative. For example, having male infertility faculty exposure impacted the

infertility training experience of urology residents, rendering them more confident in NOA management, male infertility understanding, and in performing fertility procedures after residency [18]. However, andrology/male infertility is a relatively new subspecialty comprising a minority of residency training, few institutions have andrology/male infertility faculty, most residents have inadequate andrology/male infertility exposure and variable training, and while they anticipate performing infertility procedures, they lack the confidence to do so due to the dearth of adequate exposure to this field [18,19]. Moreover, until recently, male infertility microsurgery training milestones have not been published [20]. The urologist's training in andrology does not end with residency; continuing education and training are required to keep up with the rapidly increasing advances in the field [21]. The above considerations acted as the drivers for the masterclass described in the present paper. The current study aimed to appraise the impact of an online mTESE masterclass tailored for the andrology workforce worldwide. The specific objectives were to: 1) describe the process, scientific content, and selected case discussions that comprised the masterclass; 2) assess the attainment of knowledge and skills required for appropriate assessment of the patient and unique circumstances before mTESE, as well as the skills underlying successful mTESE; 3) evaluate whether the knowledge impact of the masterclass was influenced by a range of participants' demographic and professional attributes (sex, professional background, years of experience, type of current practice, past mTESE training, self-rated skills in performing mTESE); and, 4) assess the participants' satisfaction with the masterclass. To the best of our knowledge, this is the first study to undertake such a task.

MATERIALS AND METHODS

1. Global Andrology Forum (GAF)

GAF, an international online working collaborative for andrological research, brings together senior and junior clinicians and researchers globally to promote high-quality andrology research. It includes dedicated and committed andrologists, urologists, uro-andrologists, gynecologists, embryologists, reproductive endocrinologists, and biomedical researchers from 77 countries. A detailed description of GAF's vision, mission,

management, and evolution, as well as its educational webinars, hybrid scientific meetings, online research projects, online global surveys, and scientific publication activities, have been detailed elsewhere [22-24].

2. Setting

The present masterclass was organized by GAF in collaboration with the Turkish Urology Association (TUA) during the annual TUA Symposium (13–16 March 2023). The masterclass was a hybrid activity, where some participants physically attended it in Antalya, Turkey; and the remaining global participants attended virtually through GAF's Zoom platform.

3. Event: mTESE masterclass

The main theme of this two-hour masterclass was mTESE, with emphasis on how to optimize its outcome in NOA patients. The content was developed by the GAF committee based on contemporary literature and evidence-based recommendations. First, five didactic lectures were delivered by internationally renowned experts in male infertility management from five different countries. Four of these lectures were delivered virtually, while the fifth lecture was delivered physically by the senior andrologist instructing the masterclass in Turkey whilst simultaneously being broadcasted virtually to a global audience (Supplement File 1).

These five lectures were then followed by presentations of four varied and difficult NOA cases. These

presentations were used as a platform for in-depth discussions employing the different case scenarios to debate the topics and deliberate the management of each case through interactive dialogues between moderators, panelists, and both the physical and virtual participants. Table 1 outlines the masterclass program and the different topics addressed. In addition, Supplement File 2 summarizes the four NOA cases that were presented by the moderators and discussed by the panelists and participants.

4. Ethical approval and data collection

The current study was approved by the Internal Review Board (IR-02-23-101). All participants consented to the use of their demographic data and quiz and satisfaction scores. The data was deidentified such that names, emails and mobile numbers were removed and coding was used to ensure privacy of information.

5. Survey questionnaires

Three questionnaires were used to collect the data of the participants, namely demographics, pre- and post-quiz and satisfaction questionnaires.

1) Baseline characteristics

This included demographics *e.g.*, age, sex, country, professional background, health care practice setting, years in practice, and reason/s for attending the masterclass. In addition, detailed data were also collected

Table 1. mTESE masterclass content: title, outline, and scientific sessions

| mTESE masterclass: secrets for successful outcomes | |
|--|---|
| Session | Moderator/s, speakers, and panelists |
| Welcome and introduction | USA, Turkey |
| Testicular anatomy with emphasis on mTESE | Turkey |
| Detailed technique of mTESE procedure | India |
| Comparison of ejaculated vs. testicular sperm for successful ICSI | Greece |
| Hormonal therapy after failed mTESE, is it justified? | Qatar |
| Embryologist's role during mTESE | Mexico |
| Questions and answers | All |
| Case discussions | |
| Case 1: Management of Repeat mTESE | USA, Italy, Switzerland |
| Case 2: Clinical and technical aspects of mTESE for NOA | Indonesia, Saudi Arabia, Turkey, Greece |
| Case 3: Sperm retrieval in Klinefelter's syndrome - Pre and post hormone therapy, success rates, genetic outcome | Turkey, Indonesia, Vietnam |
| Case 4: Hormonal therapy prior to mTESE—Three different case scenarios | India, UAE, Austria, Morocco |
| Take Home Message—The science and art of mTESE | Turkey, India |

mTESE: microsurgical testicular sperm extraction, ICSI: intracytoplasmic sperm injection, NOA: non-obstructive azoospermia.

pertaining to mTESE experience and training for each attendee. Baseline information also included whether the participant had: 1) Performed mTESE and its frequency; 2) Received any past mTESE training, along with the length of training; 3) Type of mTESE training undertaken; 4) Use of magnification or otherwise when performing mTESE; 4) Self-rated skills in performing mTESE; 5) Perceived need for mTESE training/guidance; and 6) Good mTESE training available.

2) Pre- and post-quiz

This quiz was designed to assess the participants' mTESE knowledge and skills prior to and then again after attending the masterclass in order to gauge the acquisition of learning attributable to the masterclass. The quiz comprised a battery of 24 multiple choice questions tapping information used to gauge different aspects of the participants' mTESE awareness, understanding and expertise (Supplement File 3). The scientific content of the masterclass covered all the topics of the quiz. The pre-/post-quiz were delivered *via* Google Form platform. The links to the Google Form were distributed by email and WhatsApp. The pre-quiz was distributed 10 days before the masterclass to all participants who registered and was kept active until half an hour prior to the actual event, while the post-quiz was distributed just after the masterclass and kept active for 48 hours.

3) Satisfaction questionnaire

Participants rated their satisfaction with the masterclass' scientific content, topics, and quality, and whether they were likely to recommend such future GAF masterclasses or webinars to their friends or colleagues. In addition, they also rated the case presentations/discussions in terms of their clinical relevance, content, and whether the discussions were fruitful in clearing the doubts that participants may have had. Responses used a 6-point Likert scale format (0=least favorable response, 5=most favorable response).

6. Statistical analysis

All statistical analyses were undertaken in Statistical Package for Social Sciences (SPSS) (version 20.0; IBM Corp.) Descriptive statistics for categorical variables were presented as frequency and percentage of the group sample, while continuous variables were presented as group means and standard deviations. Differences

in categorical demographic characteristics between respondents who registered and those who completed the survey were tested using Pearson's chi-square test. The educational and knowledge achievement impact of the masterclass was tested by comparing the frequency of correct responses to individual questions, pre-/post-quiz for the total sample, and for individual groups based on demographic and professional attributes (sex, professional background, years of experience, type of current practice, past mTESE training, self-rated skills in performing mTESE). The frequency of correct responses to individual quiz questions pre- and post were tested for significant differences using McNemar's chi-square test for repeated measures. The within-group differences (pre-/post-quiz scores) for the total sample and within-groups were tested using paired-samples t-test. Between-group quiz score differences at baseline and after the masterclass were tested using independent samples t-tests. Group-by-time interactions for pre-post changes in quiz scores were tested using split-plot analysis of variance (ANOVA) of the raw test score data. The significance level was set at $p < 0.05$.

Table 2. Demographics of members who registered for mTESE training and those who completed the survey

| Characteristic | Registered (n=1,025) | Completed the surveys (n=163) | p-value ^a |
|---------------------|----------------------|-------------------------------|----------------------|
| Age (y) | | | 0.329 |
| 20–29 | 204 (19.9) | 34 (20.86) | |
| 30–39 | 425 (41.5) | 72 (44.17) | |
| 40–49 | 218 (21.3) | 38 (23.31) | |
| 50–59 | 116 (11.3) | 16 (9.82) | |
| 60–69 | 47 (4.6) | 3 (1.84) | |
| ≥70 | 15 (1.5) | 0 (0.00) | |
| Sex | | | 0.762 |
| Male | 834 (81.4) | 131 (80.37) | |
| Female | 191 (18.6) | 32 (19.63) | |
| Continent of origin | | | 0.001* |
| Asia | 706 (68.88) | 127 (77.91) | |
| Africa | 115 (11.22) | 18 (11.04) | |
| Europe | 106 (10.34) | 17 (10.43) | |
| North America | 62 (6.05) | 1 (0.61) | |
| South America | 35 (3.41) | 0 (0) | |
| Australia | 1 (0.10) | 0 (0) | |

Cell values represent frequency (%).

mTESE: microsurgical testicular sperm extraction.

^aPearson's chi-square.

*Statistical significance ($p < 0.05$).

RESULTS

A total of 1,025 participants initially registered, of which 163 completed both the pre- and post-quiz and the questionnaire and were included in further analysis.

1. Characteristics of the sample

Table 2 depicts the demographics of members who registered for the mTESE masterclass and those who completed the surveys. Participants' age ranged from 20 to 70 years old, with more male participants than females. There was no significant difference between candidates who registered and those who completed the survey with regard to age and sex. Participants represented 6 different continents, with the majority from Asia followed by Africa and Europe. There was a statistically significant difference between registered candidates and those who completed the survey with

regard to their continent of origin.

Table 3 shows the professional characteristics of members who registered for the masterclass and those who completed the surveys. Most members who registered or completed the surveys had clinical backgrounds. There was a significant difference between the members who registered and those who completed the surveys with regard to their precise professional background, however, when their professional backgrounds were categorized into clinical *vs.* non-clinical, there was no significant difference between both groups. As for the work settings, most of the members who registered and those who completed the surveys were working in public settings, with no statistically significant difference between the two groups. Interesting topics were the primary motive for participants to participate in the masterclass, followed by the presence of renowned presenters, and finally, mTESE training

Table 3. Professional characteristics of members who registered for mTESE training and those who completed the surveys

| Characteristic | Registered (n=1,025) | Completed the surveys (n=163) | p-value ^a |
|-------------------------------------|----------------------|-------------------------------|----------------------|
| Professional background | | | 0.006* |
| Urologist | 559 (54.54) | 69 (42.33) | |
| Embryologist/laboratory andrologist | 146 (14.24) | 20 (12.27) | |
| Resident | 102 (9.95) | 26 (15.95) | |
| Clinical andrologist | 99 (9.66) | 30 (18.40) | |
| Gynecologist | 52 (5.07) | 9 (5.52) | |
| Researcher | 37 (3.61) | 4 (2.45) | |
| General practitioner | 21 (2.05) | 5 (3.07) | |
| Endocrinologist | 2 (0.20) | 0 (0) | |
| Professional background | | | 0.567 |
| Clinical | 733 (71.5) | 113 (69.3) | |
| Non-clinical | 292 (28.5) | 50 (30.7) | |
| Healthcare practice setting | | | 0.909 |
| Public | 665 (64.9) | 105 (64.4) | |
| Private | 360 (35.1) | 58 (35.6) | |
| Years of experience | | | 0.491 |
| >5 | 514 (50.15) | 77 (47.76) | |
| ≤5 | 511 (49.85) | 86 (52.76) | |
| Reason/s for attending the webinar | | | |
| Interesting topics | 898 (87.61) | 140 (85.89) | 0.539 |
| Renowned large number of experts | 429 (41.85) | 79 (48.47) | 0.113 |
| Required for current job | 289 (28.20) | 61 (37.42) | 0.016* |
| Required for future job application | 122 (11.90) | 24 (14.72) | 0.327 |
| Other | 18 (1.76) | 2 (1.23) | 0.626 |

Cell values represent frequency (%).

mTESE: microscopic testicular sperm extraction.

^aPearson's chi-square.

*Statistical significance (p<0.05).

Table 4. Previous mTESE training and experience of members who completed the surveys

| Characteristic | Number of participants who completed the surveys (n=163) |
|--|--|
| Perform mTESE | |
| Never | 72 (44.17) |
| Occasionally | 36 (22.09) |
| Frequently | 34 (20.86) |
| Routinely | 21 (12.88) |
| Received past training in performing mTESE | |
| No | 93 (57.06) |
| Yes | 70 (42.94) |
| Length of training ^a | |
| <1 month | 37 (52.86) |
| ≥1 month | 33 (47.14) |
| Type of past mTESE training undertaken | |
| Watched videos | 90 (55.21) |
| Attended symposia/lectures | 57 (34.97) |
| Assisted in actual procedures | 43 (26.38) |
| Performed procedures with expert assistance | 43 (26.38) |
| Observer at high volume center for ≥1 week | 37 (22.70) |
| Self-taught | 31 (19.02) |
| Training on cadaveric/animal model | 9 (5.52) |
| I usually perform mTESE | |
| Do not perform mTESE | 72 (44.17) |
| With operating microscope | 62 (38.04) |
| With operating loupes | 15 (9.25) |
| Without magnification | 14 (8.59) |
| Self-rated skills in performing mTESE ^b | |
| 1 | 76 (46.63) |
| 2 | 9 (5.52) |
| 3 | 33 (20.25) |
| 4 | 34 (20.86) |
| 5 | 11 (6.75) |
| Need for mTESE training/guidance | |
| Yes, I need considerably more training/guidance | 98 (60.12) |
| Yes, I need some more training/guidance | 37 (22.70) |
| No, but symposia like this will enhance my skills | 24 (14.72) |
| No, my knowledge/skills in mTESE are complete | 4 (2.45) |
| Good mTESE training is | |
| Easily available | 15 (9.20) |
| Available with difficulty | 50 (30.67) |
| Not available to me | 30 (18.40) |
| No response | 68 (41.72) |

Cell values represent frequency (%).

mTESE: microscopic testicular sperm extraction.

^aValues calculated as percent of respondents who stated 'yes' to whether they have received mTESE training. ^bOn a scale of 1=low level of skills to 5=very high level of skills.

was a job requirement.

Table 4 details the information regarding participants' mTESE experience and training, comprising data from participants who completed all 3 questionnaires (n=163). Most participants never/occasionally performed mTESE. Likewise, most did not receive mTESE training. For those who received previous mTESE training, nearly equal percentages attended training that was either <1 month or >1 month. The types of training attended ranged from watching videos or presentations to hands-on training on cadavers or patients with expert assistance. For those with mTESE experience, the majority used surgical microscopes for the operation. Nearly half the participants self-rated their mTESE skills as low, while only a minority (11%) rated themselves as very high. Whilst about 83% of the participants emphasized their need for mTESE training and guidance, roughly half the participants declared that good mTESE training was either unavailable or available with difficulty.

2. mTESE knowledge and skills before and after the masterclass

Table 5 shows the comparison between the numbers (and percentages) of participants who answered the pre- and post-quiz correctly categorized by the individual quiz questions. There were significant improvements in the number of participants with correct responses in 19 of the 24 questions in the post-quiz compared to the pre-quiz indicating enhanced knowledge across several knowledge domains.

3. Improvements in mTESE knowledge/skills by demographic and professional attributes

Table 6 depicts the changes in the pre-and post-quiz mean total scores for the whole sample and by selected participant characteristics. The total score improved significantly in the post-quiz compared to the pre-quiz. As for the selected characteristics, for the professional background, clinicians had significantly higher scores in the pre-quiz, however, this difference became insignificant in the post-quiz. Similarly, those who received previous mTESE training and those who rated themselves as having higher mTESE skills had significantly higher pre-quiz scores compared to those who did not receive training and those who rated themselves as having lower mTESE skills respectively, but again

Table 5. Pre-/post-quiz: comparison of mTESE knowledge and skills before and after the masterclass

| Question | Pre-quiz | Post-quiz | p-value ^a |
|--|------------|------------|----------------------|
| 1) Evidence-based guidelines for HT in NOA include ^b | 133 (81.6) | 135 (82.8) | 0.860 |
| 2) Intratesticular T levels ^c | 95 (58.3) | 132 (81.0) | <0.001* |
| 3) Indication for AI HT in NOA is an E:T ratio of >1/10 ^b | 115 (70.6) | 115 (70.6) | 1.000 |
| 4) Surgical SR rates in NOA with HH increase after HT for optimization ^b | 78 (47.9) | 97 (59.5) | 0.007* |
| 5) HT adverse outcomes before SR does not include ^b | 59 (36.2) | 84 (51.5) | <0.001* |
| 6) AUA/ASRM guidelines support AI routine use as HT to optimize spermatogenesis prior to SR ^b | 102 (62.6) | 125 (76.7) | 0.001* |
| 7) Which is incorrect for FSH measurement in Az ^d | 82 (50.3) | 111 (68.1) | <0.001* |
| 8) Incorrect for Az with HH ^c | 102 (62.6) | 129 (79.1) | <0.001* |
| 9) Incorrect for HT pre-mTESE ^b | 107 (65.6) | 131 (80.4) | <0.001* |
| 10) In pre-mTESE HT, the following are treatment options except ^b | 115 (70.6) | 140 (85.9) | <0.001* |
| 11) Most frequent genetic abnormality in infertile Az men is ^c | 144 (88.3) | 157 (96.3) | 0.001* |
| 12) mTESE expected SR rate in Az men with KS ^c | 77 (47.2) | 107 (65.6) | <0.001* |
| 13) Predictors of mTESE success in Az men with KS ^c | 67 (41.1) | 99 (60.7) | <0.001* |
| 14) Not true for KS ^c | 94 (57.7) | 115 (70.6) | 0.003* |
| 15) True for KS ^c | 77 (47.2) | 87 (53.4) | 0.212 |
| 16) In KS, the risk is not increased for ^c | 88 (54.0) | 116 (71.2) | <0.001* |
| 17) Magnification for effective mTESE is ^e | 86 (52.8) | 100 (61.3) | 0.070 |
| 18) T 260 ng/dl, Gn normal. Before mTESE, improve SR by ^b | 104 (63.8) | 124 (76.1) | 0.001* |
| 19) T 260, FSH 17, LH 6, E 9, P 11. Medication appropriate before mTESE ^b | 66 (40.5) | 108 (66.3) | <0.001* |
| 20) Repair palpable varicocele before mTESE in NOA is for ^b | 130 (79.8) | 141 (86.5) | 0.080 |
| 21) Before mTESE, lab tests needed ^b | 85 (52.1) | 106 (65.0) | 0.004* |
| 22) For failed mTESE, the following should be done ^b | 78 (47.9) | 112 (68.7) | <0.001* |
| 23) True about FSH ^c | 77 (47.2) | 102 (62.6) | 0.001* |
| 24) In NOA, the potential benefit of fresh vs. frozen testicular sperm ^e | 74 (45.4) | 108 (66.3) | <0.001* |

Cell values represent the frequency (%) of respondents with correct answers for the given question pre- and post-webinar.

AI: aromatase inhibitors, AUA/ASRM: American Urological Association/American Society for Reproductive Medicine, Az: azoospermic/azoospermia, E: estradiol, FSH: follicle-stimulating hormone, Gn: gonadotrophin, HH: hypogonadotropic hypogonadism, HT: hormonal therapy, KS: Klinefelter's syndrome, LH: luteinizing hormone, mTESE: microscopic testicular sperm extraction, NOA: non-obstructive azoospermia, P: prolactin, SR: sperm retrieval, T: testosterone.

^aMcNemar's chi-square test. ^bPreoperative preparation. ^cBasic knowledge. ^dDiagnosis. ^eOperative details.

*Statistical significance (p<0.05).

these differences became insignificant in the post-quiz. Sex, years of experience, and practice setting did not significantly affect the pre- or post-quiz scores.

As for the percent change in quiz scores by professional characteristics, participants with non-clinical backgrounds improved relatively more than those with clinical backgrounds (49.34% improvement from pre-quiz score *vs.* 27.05%, respectively, p=0.044). Likewise, those with ≤5 years' experience improved significantly relatively more than participants with >5 years' experience (p=0.038); those in public practice improved significantly relatively more than participants in private practice (p=0.029); and for self-rated skills, those with lower self-rating (1–3) in performing mTESE improved significantly relatively more than those with higher

self-rating of 4–5 (p=0.04).

4. Satisfaction with the mTESE masterclass

Table 7 shows participants' satisfaction with the masterclass webinar. Nearly all the participants were very highly satisfied with masterclass generally, as well as with the different aspects, quality, clinical relevance, and content of the mTESE masterclass and case discussions.

DISCUSSION

Although NOA is the most severe form of male infertility, the chance of biological fatherhood for these men has improved since the introduction of mTESE

Table 6. Changes in pre- and post-mTESE quiz scores by selected participant characteristics

| Characteristic | Total score | | p-value ^a | % Δ change | Group*time interaction ^b |
|--|-------------------------|------------|----------------------|-------------|-------------------------------------|
| | Pre-test | Post-test | | | |
| Total sample | 13.71±4.13 | 17.06±4.73 | <0.001* | | |
| Professional background | | | | | |
| Non-clinical | 11.86±4.12 ^c | 16.34±5.82 | <0.001* | 49.34±74.38 | |
| Clinical | 14.53±3.88 | 17.38±4.15 | <0.001* | 27.05±49.82 | |
| p-value ^d | <0.001* | 0.257 | | | 0.044* |
| Sex | | | | | |
| Male | 14.02±4.13 | 17.31±4.56 | <0.001* | 32.68±57.81 | |
| Female | 12.47±3.98 | 16.06±5.35 | <0.001* | 38.87±64.99 | |
| p-value ^d | 0.057 | 0.233 | | | 0.748 |
| Experience (y) | | | | | |
| ≤5 | 13.27±4.01 | 17.35±5.06 | <0.001* | 41.18±65.58 | |
| >5 | 14.21±4.23 | 16.74±4.35 | <0.001* | 25.75±50.15 | |
| p-value ^d | 0.147 | 0.414 | | | 0.038* |
| Practice type | | | | | |
| Public | 13.64±4.25 | 17.59±4.96 | <0.001* | 40.27±66.28 | |
| Private | 13.84±3.94 | 16.10±4.15 | <0.001* | 22.34±41.34 | |
| p-value ^d | 0.761 | 0.054 | | | 0.029* |
| Received mTESE training in the past | | | | | |
| No | 13.14±4.04 | 16.77±4.88 | <0.001* | 37.79±60.93 | |
| Yes | 14.47±4.15 | 17.44±4.53 | <0.001* | 28.71±56.65 | |
| p-value ^d | 0.041* | 0.373 | | | 0.381 |
| Self-rated skills in performing mTESE ^b | | | | | |
| 1–3 | 12.97±3.97 | 16.79±4.97 | <0.001* | 40.17±64.67 | |
| 4–5 | 15.67±3.94 | 17.78±3.99 | <0.001* | 17.44±36.99 | |
| p-value ^d | <0.001* | 0.191 | | | 0.040* |

Cell values represent mean±standard deviation.

mTESE: microscopic testicular sperm extraction.

^aPaired-samples t-tests for within-group differences. ^bGroup-by-time interactions represent the results of a split-plot analysis of variance (ANOVA) for each grouping, reflecting the comparison of the % change across groups and time. ^cThis group included many residents. ^dIndependent samples t-tests for between-group differences.

*Statistical significance (p<0.05).

combined with ICSI [25]. mTESE has a higher sperm retrieval rate with fewer postoperative complications and adverse effects on testicular function than conventional TESE [26]. As our understanding of and appreciation for the complexities of reproductive medicine continue to grow, the wide breadth of knowledge domains required for the evaluation, selection, and preparation of potential patients for mTESE becomes more evident. Likewise, performing this microsurgical procedure successfully necessitates extensive skills to maximize the sperm retrieval rate effectively and minimize complications.

In response to the need for such wide-ranging and high-level abilities, GAF tailored and presented a detailed mTESE masterclass, that uniquely combined

didactic lectures with case discussions. The masterclass started with a series of didactic lectures beginning with the anatomy, tips, and tricks of the mTESE technique, and ending with a range of tactics, strategies, and pearls aimed at the optimization of mTESE outcomes in various clinical scenarios. These didactic lectures were followed by four case scenarios of diverse, complex NOA cases that reflect varied, challenging conditions and heterogenous debatable situations that the andrology team could face during NOA management. The current study is the first to appraise the impact of such an online mTESE masterclass custom-built for the andrology workforce worldwide.

Our main findings were remarkable. First, the mTESE masterclass' scientific content pertaining to

Table 7. Member satisfaction with mTESE knowledge and skills masterclass

| Aspect of webinar | Satisfied ^a | Satisfaction level | |
|----------------------------------|------------------------|----------------------|--------|
| | n (%) | Mean±SD ^b | Median |
| Content | | | |
| Overall topic | 208 (99.52) | 4.60±0.61 | 5 |
| Overall quality | 205 (98.09) | 4.55±0.66 | 5 |
| Likely to recommend ^c | 206 (98.56) | 4.65±0.63 | 5 |
| Ratings of case discussions | | | |
| Case 1 | | | |
| Clinical relevance | 207 (99.04) | 4.53±0.68 | 5 |
| Content | 205 (98.09) | 4.53±0.70 | 5 |
| Doubts cleared | 205 (98.09) | 4.34±0.76 | 4 |
| Case 2 | | | |
| Clinical relevance | 207 (99.04) | 4.57±0.61 | 5 |
| Content | 206 (98.56) | 4.51±0.67 | 5 |
| Doubts cleared | 205 (98.09) | 4.40±0.72 | 5 |
| Case 3 | | | |
| Clinical relevance | 208 (99.52) | 4.58±0.62 | 5 |
| Content | 204 (97.61) | 4.44±0.72 | 5 |
| Doubts cleared | 205 (98.09) | 4.44±0.74 | 5 |
| Case 4 | | | |
| Clinical relevance | 204 (97.61) | 4.53±0.70 | 5 |
| Content | 204 (97.61) | 4.44±0.73 | 5 |
| Doubts cleared | 204 (97.61) | 4.41±0.76 | 5 |

mTESE: microscopic testicular sperm extraction.

^aValues represent frequency (%) of respondents reporting satisfaction (≥3 on response scale of 0–5). ^bValues represent mean satisfaction score±SD of participants. ^cRecommend future webinars to friends/colleagues.

*Statistical significance (p<0.05).

the lectures and in-depth case presentations and discussions solidly covered the range of topics, knowledge and abilities that are seminally required by andrology practitioners. Participants' satisfaction with the webinar's topics, quality, clinical relevance, and content was very high, ranging from 98% to above 99%.

Second, the improvements in respondents' knowledge and skills after the masterclass were notable and exhibited five striking characteristics. Based on the improvements we observed, the acquired learning was characterized by being:

- a) Broad *i.e.*, across many mTESE domains and skill areas, evidenced by the breadth of learning where for 19 out of the 24 quiz questions, there were significant increases in the numbers of participants correctly answering the questions in the post-quiz compared to the pre-quiz;

- b) Deep *i.e.*, of magnitude, reflected by improvement from a mean total pre-quiz score of 13.71±4.13 to a post-quiz mean of 17.06±4.73, signifying the extent of learning;

- c) Highly significant *i.e.*, real, not due to chance, and with high p-values, consistently <0.001, signaling entrenched, well-established learning;

- d) Inclusive *i.e.*, across the board for all participants, indicating an all-encompassing learning process, as all participants enhanced their mTESE knowledge and skills after the masterclass regardless of their sex, professional background, past experience, practice type, past mTESE training, and initial pre-masterclass self-rated skills in performing mTESE; and,

- e) Differential *i.e.*, exhibiting different improvement rates for different groups, and these differences in learning were at times statistically significant. For instance, although both participants with non-clinical and clinical backgrounds improved, the former improved relatively more than the latter (49.34% improvement from pre-quiz scores *vs.* 27.05%, respectively). This phenomenon was also observed for years of experience, where those with less experience (≤5 years) improved significantly relatively more than participants with more experience (>5 years); and practice type, where those in public practice improved significantly relatively more than participants in private practice; and those with lower self-rated mTESE performance skills improved significantly relatively more than participants with higher self-rating. Below we discuss our findings in detail.

In terms of the participant sample, although only 163 GAF members completed the surveys out of 1,025 who registered, however, the demographic and professional characteristics of the former group were not significantly different from the latter, suggesting that those included in the current analysis indeed were representative of the greater GAF membership. A requisite for obtaining the official GAF certificate of attendance was the completion of the surveys, hence, in reality, many more members actually attended the masterclass but did not complete the surveys, as obtaining the attendance certificate was perceived as not important for them. This is evidenced by our survey question of the reason(s) for attending the masterclass, where significantly more participants who completed the survey

compared to those who registered reported that the reason was that it was required for their current job.

The participants' professional backgrounds encompassed all sub-specialities—urologists, clinical andrologists, and gynaecologists—supporting research findings that even when dealing with male infertility a collaboration between both male and female reproductive experts is important for ensuring that the most appropriate treatment is provided based on the couple's goals and priorities [27].

Our participants also included general practitioners, the critical gatekeepers who frequently are the first to identify a potential case and initiate the referral process of such infertile men to the next tier of care, *e.g.*, a reproductive urologist, who can then diagnose the condition and provide appropriate therapy. Similarly, the group also included embryologists and laboratory andrologists, who represent the next tier in handling the extracted testicular tissue to identify suitable and viable sperm [28]. For embryologists, mTESE is the preferred surgical sperm retrieval technique since it facilitates selection of tubules most likely to contain sperm, thus saving the embryologist the effort and time to search through a large amount of tissue [29,30].

In connection with previous mTESE training and experience, about half of our sample (44%) had never performed mTESE and 57% had not received past training in performing mTESE. Our findings resonate with a general widespread knowledge and skills deficiency that others have identified. In Finland, physicians and specialists needed to be made aware of new treatment options to enable biological fatherhood for NOA men [31].

Few residency training programs include infertility, and most residents lack the confidence to perform infertility procedures because of variable training and inadequate exposure to the field [18,19]. Collectively, this widespread deficiency in training schemes and inadequate exposure thereafter evident in the literature only serves to highlight the urgent need and pressing importance of timely and relevant masterclasses such as the one described and evaluated in the current study. Future research could urgently address the types and causes of such deficiencies as well as potential policies and effective strategies to address them.

In connection with the impact of the present masterclass, we observed heightened knowledge and boosted skills across many mTESE learning domains and skill

areas (19 out of the 24 quiz questions) after the masterclass as outlined above. Our findings confirm that the knowledge and skills improvements reflected learning that was characterized by being broad, deep, highly significant, inclusive and differential.

To the best of our knowledge, we are not aware of published research that assessed the knowledge and skills impact of mTESE training. A notable exception to the non-existent literature on the topic is a study in Japan that demonstrated that as NOA caseloads increase, surgical outcomes and sperm retrieval rates improve, confirming a substantial learning curve for mTESE [9]. In NOA, the frequently observed absence of uniformity in testicular tissue is critical to successful mTESE, whereby when the better/best portion can be microscopically identified, there is an increased chance to retrieve testicular sperm [9]. Such improvements that accrue with heightened knowledge and boosted skills are not only evident for the surgeons who perform mTESE. The embryologists' learning curves are just as important, and with experience and training, the sperm retrieval rates improve and the time to find sperm may shorten [9]. Collectively, the above findings further emphasize the critical significance of masterclasses such as the one we describe and evaluate in this paper. Andrologists need to actively learn to maximize the sperm recovery rate whilst minimizing unnecessary damage to the testis [9].

The literature revealed a 'slayer' gap of knowledge. There is an unmistakably notable lack of published studies that assess the extent to which andrology team members' training, knowledge, and adequate exposure impact on mTESE outcomes. This lack is despite the abundant body of parallel literature in other related fields including *e.g.*, laparoscopic procedures, where clinical outcomes were correlated with the quality of surgery, thus emphasizing the utility of surgical education and quality assessment [32]. Similarly, in relation to minimally invasive surgery, training enhanced surgical performance with a positive impact on performance and error rate [33].

Yet, in andrology, when the current and 'recently published' mTESE literature is examined *e.g.*, when mTESE in NOA men is summarized [34]; or when factors predicting successful sperm retrieval among NOA men are assessed [13]; or when mTESE sperm extraction results of the first 100 patients are appraised [31]; or when the clinical experience of mTESE is evaluated

[35], there is lack of acknowledgement of the need for skill building courses, such as the one described and evaluated here, to improve andrologists' ability to perform mTESE optimally.

This study has some limitations. We evaluated only one masterclass. Although those members who completed the questionnaire amounted to about 16% of those who registered, however, there were no significant differences between the two groups with regards to age, sex, work settings, and clinical *vs.* non-clinical background, and hence the results have some generalisability. We are unable to comment on longer-term knowledge retention as the post-test was undertaken soon after the masterclass. Future research should address these limitations.

The current study has many strengths. To the best of our knowledge, this is the first study to appraise the impact of an online mTESE masterclass for the andrology workforce worldwide. The present study described the content of the masterclass, appraised the acquisition of mTESE knowledge and skills, assessed whether the accomplishment of knowledge was influenced by participants' demographic and professional attributes, and measures satisfaction with the masterclass. We are not aware of other studies that have undertaken such a task and performed an in-depth evaluation such as that reported here.

CONCLUSIONS

GAF's mTESE Masterclass described in this paper was a definite success. Participants' satisfaction was very high, and their mTESE knowledge and skills notably improved after the masterclass. Such improvements were characterized by learning that was broad, deep, highly significant, inclusive, and differential. An additional benefit is that the participants who most needed mTESE knowledge and skills were the precise ones who improved the most, namely non-clinical practitioners with ≤ 5 years of experience serving in public practice, as well as clinical practitioners with low self-rated mTESE performance. Andrological local agencies, national consortia, regional associations, and international bodies would benefit their workforce by implementing and developing the GAF's Masterclass model to enhance their experts' mTESE knowledge and skills in a rapidly evolving field requiring considerable learning and expertise. Future research would need

to appraise such mTESE educational masterclasses in order to develop the practically non-existent evidence base.

Conflict of Interest

The authors have nothing to disclose.

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Author Contribution

Conceptualization: AA, RS, WEA. Statistical analysis: ML. Supervision: WEA. Writing - original draft: WEA, AA. Writing - review and editing: all authors. All authors have read and agreed to the published version of the manuscript.

Supplementary Materials

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