Bedside Evaluation of Edema: A simple technique for quantitative evaluation of an important clinical sign

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Method Article

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Abstract

Background: Edema is a cardinal clinical manifestation. Most clinicians measure edema semi-quantitatively, which is susceptible to subjective and non-reproducible intra- and inter-observer variation. A quick and reliable quantitative method is needed for more accurate measurement.

Objective: To demonstrate the reliability of a new clinical examination technique, verified against a novel edema measuring device.

Design: A convenience sample enrolled in one day at a community hospital.

Patients: Seventeen adult patients with various clinical conditions. One patient was not examined by request and was excluded from analysis.

Interventions: Clinical and device estimation of pit depth of edema created by manual pressure at a standard location on 27 limbs.

Key Results: Clinical and device measurements were precisely the same 50% of the time; differences in measurements never exceeded 1 mm. The 95% confidence interval was 0.21 with an R^2 statistic of 0.87 for all depths of edema, using either clinical or device measurement as the criterion standard, demonstrating excellent correlation between clinical examination and use of the device.

Conclusions: Clinical evaluation can estimate edema pit depth in millimeters very accurately. A novel edema measuring device confirms these measurements independently and objectively. It is hypothesized that this new technique will help standardize the teaching of the clinical examination of edema, increase the utility of edema depth measurement over time, and increase intra- and inter-observer reliability of edema evaluation. There is no longer a justification for semi-quantitative determination of edema.

NIH trial registry number: NCT03296085

Introduction

Edema is a cardinal sign of numerous clinical conditions, yet its evaluation remains poorly taught in medical and nursing education. The 3rd edition of DeGowin and DeGowin(1) advocated that clinicians measure edema by pressing on an area of swelling, and then “the *depth* of the pit *should be estimated and recorded in millimeters*, shunning such meaningless expressions as ‘three-plus’” [emphasis mine]. The 10th edition states(2) that one should “look for edema” on the legs and feet, but there are no other instructions nor is the term found in the index. Later this text implies that edema differs from lymphedema in that the latter “may pit at first, but characteristically is not pitting.”(2)The 11th edition,(3) however, does define pitting edema as when “gently pressing a thumb into the skin against a bony surface [where] an indentation persists” but there is no guidance such as offered by the 3rd edition.

Despite DeGowins' wise admonition in its earlier edition, all major textbooks, including in specialty fields that are concerned with the myriad conditions that cause edema advocate instead a semi-quantitative evaluation of this important finding or fail to give any quantitative instructions.

An early edition of the popular Bates' physical examination guide(4) instructs the examiner to maintain thumb pressure for 5 seconds. A later edition(5) suggests using one's thumb to "press firmly but gently. .. for at least 2 seconds. .. The severity of edema is graded on a four-point scale, from slight to very marked." Fig. 12–25 in Bates shows a picture of what the authors call 3 + edema.(5) No mention is made of the duration of the pitting. There is no evidence offered in the later edition for this change. The earlier Bates' edition also suggests measurement of leg circumference with a flexible tape. The implication is that this modification of measuring edema is useful "to follow its course"(4) over time. This was dropped from the later edition.

Harrison's textbook of medicine discusses edema at great length, and defines pitting much like Bates' as "persistence of an indentation of the skin after pressure." It does not instruct the reader where to examine for, judge the amount of, nor even semi-quantitively estimate edema severity, although refers to various degrees of edema as important in the diagnosis of various conditions.(6)

Goldman-Cecil's Textbook of Medicine(7) stresses the importance of edema as "a cardinal manifestation" of multiple diseases but makes no mention of how to evaluate or measure this sign.

An earlier edition of Brenner and Rector's renal textbook(8) advises pressing the thumb against the tibia or sacrum, observing for "the resulting pit", and grading the severity on a scale of 1 to 4, further asserting that "deep pitting that persist(s) for > 2 minutes" suggests severe edema. The most recent edition makes no mention of this.(9)

Aside from vague remarks regarding "excess fluid" or "minor degrees of edema", Hurst's textbook of cardiology(10) goes no further to instruct us how to evaluate this important clinical finding other than "examination of the lower extremities for edema. .. should be done".

Seidel's (formerly Mosby's) manual(11) on physical examination, mainly intended for nurses, implies in a figure that pit depth can be measured in millimeters, but the text states that "severity of edema may be characterized by grading 1 + through 4+." The diagram further suggests that the semiquantitative grading system correlates with 2 mm increments of pit depth. This text states that the duration of pitting correlates with edema severity but the author offers no evidence nor supplementary discussion for either of these claims.

Even UpToDate fails to instruct clinicians how to measure edema other than to remark that "testing for pitting involves applying firm pressure to the edematous tissue for at least five seconds."(12)

If the number of objective research methods that are available to measure edema is any indication, it is indeed a difficult task. These include the time-honored, but basically untested pit depth estimation mentioned by DeGowin and DeGowin and others, with or without an estimate of the duration of the pitting. Other methods include water-displacement volumetry (WDV),(13) measurements of ankle or figure-of-eight circumference, indirect estimates of leg volume by the disk model, and various modalities of edema testers.(14) Water immersion volumetry has been considered the criterion standard, but even this has been called into question by techniques such as optoelectronic volumetry.(15) Bioimpedance spectroscopy(16) (BIS) or ultrasound viscoelastography(17) offer novel techniques, but require sophisticated technology and presumably high cost. There is one important proviso regarding these techniques: none except for direct edema testers is able to determine whether a patient actually has edema: "volumetry does not quantify edema but rather the short-term variations that reflect changes in edema".(18) A handheld camera/LED light/compressed air device(19) to objectively measure edema sounds enticing, but is not practical on day-to-day basis. Measurement of tissue dielectric constant may be a sensitive test when early detection is crucial, such as lymphedema post mastectomy.(20) Other sophisticated tests, such as optoelectronic arm measurements,(20) are as cumbersome and time consuming as WDV or BIS.

At least two studies have explored the use of various direct edema testers.(7, 21) These studies used specially made devices which must be applied for two minutes under a blood pressure cuff inflated to 50 mmHg. This can be uncomfortable, requires too much time, may not be possible in patients with open ulcers, and raises concerns about microbiological contamination from patient to patient.

Many of the techniques and assessments are subjective. How much pressure should be applied, and for how long? Where is the best place to assess edema? What constitutes a "little" edema, and is one examiner's one-plus the same as another's? Is an examiner consistent from patient to patient and with one patient over time? Clinicians need a reproducible and accurate method to be able to assess excess extravascular fluid accumulation in their patients at any one point in time, and to be able to consistently evaluate changes over time.

Whatever technique is used must have *intra*-observer reliability and complex methods decrease the likelihood of reproducibility. Clinicians also need edema assessment to be rapid and easy. Any form of volumetry, no matter how accurate, is cumbersome, impractical, and time consuming. Leg circumference testing is feasible, but suffers from variations in locations for testing, snugness of application of the tape measure, and complexity for some techniques such as the figure-of-eight method.

Physicians often depend on nurses or other personnel to alert them when a patient has edema, so *inter*-observer reliability is also mandatory. It would be best to have a technique that is easy for all types of clinicians, such that everyone is able to use the same methodology. It is more likely under these circumstances that accurate conclusions can be drawn regarding the quantity of edema being evaluated.

Previous investigations which have tried to compare several of these methods have suffered from small sample sizes (20 patients) and unvalidated questionnaires, as in the Brodovicz study.(14) Patient reports of edema are notoriously inconsistent, and at best subjective. Duration of pitting has been touted as another feature susceptible to testing, but it has not been studied in any systematic fashion, takes too long, and there is poor correlation to edema severity.(15)

The author has used the clinical technique described in this article for many years and has found it useful for tracking the degree of edema in individual patients. This study attempts to make the technique objective, standardized, and independently verifiable by evaluating intra-observer correlation between this novel method of clinical examination and a novel, simple, home-made, hand-held device to measure depth of edema with accuracy within one millimeter.

Methods

The author created a novel edema tester from a standard 5 mL syringe (Fig. 1). I removed the plunger, shortened the syringe by cutting it at the 2 mL mark, and replaced the plunger in reverse fashion back into the barrel. Removing the rubber gasket at the end of the plunger allowed for more accurate measurements and easier cleaning. I attached a scale (printed from Microsoft Publisher©, Redmond, WA), adjusted to exact millimeter increments to the side of the barrel. Strips of black tape on the plunger provide a simple visual mark to measure the depth of the edema. The scale was attached at the correct position to calibrate the tape marks with the zero line, when the end of the plunger was flush with the flange. A small rubber band or O-ring around the plunger proved useful to allow smooth operation of the plunger with enough resistance to avoid slippage of the plunger.

Patients in the behavioral health, maternity, and pediatric units, and patients in isolation were excluded from screening. If patients were not in their rooms at the time of screening, no further effort was made to recruit them for this study.

Patients were asked if they would allow a momentary examination of their legs by the examiner, followed by application and measurement using the device.

The standard location for testing was selected 10 cm above the medial malleolus just medial to the tibial ridge (Fig. 2). The 10 cm mark was determined by placing the palmar aspect of the examiner’s hand, which had been previously measured to be 10 cm wide, against the patient, with the medial border of the palm overlying the malleolus and the thumb thus 10 cm above the malleolus. The examiner then applied gentle but steady pressure against the tibia, until all the edema was pressed aside, and the thumb rested against the tibial periosteum.

In some cases, there was edema of the arm(s). A location 10 cm above the ulnar styloid was determined in similar fashion, pressing against the dorsal aspect of the radius, which is less tender than along the lateral margin or on the volar aspect.

The examiner next estimated the depth of the edema by placing the index finger vertically into the depression, and placing the thumb perpendicularly across the index finger level with the surrounding skin surface (Fig. 3). With practice it becomes easy to gauge the depth of the edema from fingertip to thumb in millimeters.

In this study clinical determination of edema depth preceded use of the edema tester. The examiner placed the device at the site of the pit, resting the flange of the syringe on the undimpled skin surface. Gentle pressure against the plunger was sufficient to nestle the end of the plunger into the depression just created by the examiner's thumb. The examiner then read the depth on the millimeter scale (Fig. 4). After each measurement, the device was cleaned with an alcohol-based disinfectant.

Differences between clinical and device measurements were analyzed with standard 2-tailed t-tests, Chi squared tests, and analyses of variance. R^2 and confidence intervals were calculated, and graphs created using Microsoft Excel© (Redmond, WA) statistical software and verified by a statistician.

The patient's diagnoses were obtained from the electronic medical record, but no other patient identifying information was collected. It was felt that collection of the patient's name and other data via a consent form would have created a greater risk to patient privacy than to proceed with the research, which was classified as quality improvement and educational. The hospital's Institutional Review Board granted a waiver and no consent form was required. The ClinicalTrials.gov identifier is NCT03296085.

Results

Approximately 100 patients were screened out of a total inpatient census of approximately 150. Those that did not have any clinically detectable edema were not tested further. All were adults at least 18 years old; exact ages were not determined. Male and female patients were represented equally. Most carried diagnoses of congestive heart failure or chronic kidney disease, but their primary diagnoses for admission to hospital were highly varied (Table 1). A convenience sample of 16 patients (28 limbs) determined to have edema were the subjects for this study. All were examined on the same day.

Table 1
Distribution of diagnoses and numbers of patients with each primary diagnosis.

Primary Diagnosis	Secondary Diagnoses	Number
acute myocardial infarction	coronary artery disease, pulmonary hypertension	1
acute pancreatitis	alcoholism, drug abuse	1
cat bite	rheumatoid arthritis, diabetes mellitus	1
cellulitis	atrial fibrillation, hypertension, diabetes mellitus	1
coronary artery disease	sleep apnea, peripheral vascular disease	1
congestive heart failure	chronic kidney disease, fall, hematoma, anemia, coronary artery disease, diabetes mellitus, pleural effusion, unstable angina (among the 4)	4
gastroenteritis	dehydration, factor 5 Leiden	1
hip fracture	coronary artery disease, hypertension	1
hypercalcemia	lung mass, pleural effusion, respiratory failure	1
metastatic breast cancer	neutropenia, dehydration, hypoalbuminemia	1
pleural effusion	coronary artery disease, recent coronary artery bypass	1
seizure disorder	end stage renal disease, chronic obstructive pulmonary disease, respiratory failure	1
volume depletion disorder	acute renal failure	1
	TOTAL	16

Only one patient declined to be tested, expressing concern due to preexisting painfulness caused by cat bite cellulitis. Lack of information regarding this one patient was not felt to be a deterrent to further testing of the device or technique, and was not felt to compromise the conclusions of this report.

No patients experienced any discomfort with the examination technique, either with pressure from the examiner's thumb, or with use of the device.

Clinical and device measurement for each patient took fewer than 15 seconds combined. No attempt was made to measure the duration of pit depth, other than to assure that the pit persisted between the time it was created by the examiner and the device was applied.

The depth of edema varied in this patient group from trace (less than 0.5 mm) to 6 mm. No patient was felt clinically to have massive edema. Half the time the clinical and edema tester depths were identical. On four occasions, the difference was 0.5 mm, an interval that could only be estimated using the device. There was never more than a 1 mm difference. The raw data are available in the Supplementary Material.

The standard deviation for all of the measurements was 0.55, with a 95% confidence interval of 0.21 mm. The R^2 statistic was 0.87, demonstrating overall very high correlation between clinical and device measurements. These statistics did not vary significantly whether clinical examination or the edema tester was taken as the criterion standard. Figures 5a and 5b display a Bland-Altman plot of these correlations.

Two-tailed Student's t-test showed insignificant differences between clinical and device measurements for values below 4 mm. For values of 4 mm of clinical edema there was a significant difference in the means of measurement showing that clinical examination tended to overestimate edema depth ($p = 0.004$ for clinical as criterion standard, $p = 0.008$ for device as the criterion standard). Since there was only one measurement of edema greater than 4 mm, no statistical conclusions can be drawn. It is possible that clinical measurement may tend to overestimate massive edema, a question that only further research will answer.

Discussion

Edema is a key clinical finding, with considerable implications depending on quantitative results. The author believes that semi-quantitative analysis does not offer the clinician the accuracy one needs for comprehensive therapy. This study shows that it is easy to obtain a reliable measurement of edema in millimeters that can be verified by a simple device. Measurements can be made in a matter of seconds, and patients experience minimal if any discomfort.

One can standardize one's examination by selecting a typical location for evaluation and measurement of edema. This allows for consistent assessment over time, which was not assessed in this study. However, it is likely that a clinician's accuracy will improve over time, undoubtedly leading to greater precision of measurement and thus reliability of the technique's usefulness over time for a given patient.

This study shows that a clinical estimate alone of the depth of edema is highly accurate, and requires no special equipment. Edema measurements by clinical examination or the edema testing device were always within 1 mm. The 95% confidence interval of 0.21 mm is reassuring, whether clinical or device measurement was taken as the criterion standard. Clinical examination may overestimate edema, but further testing will be necessary to ascertain if this discrepancy occurs with larger numbers of patients with massive edema.

The edema testing device was a simple tool that others could easily reproduce. This may be useful for individuals who are learning the technique. For more extensive teaching a more durable model would be desirable. With practice, the edema testing device becomes unnecessary after one gains experience with the overall technique.

Conclusions

This study demonstrates that edema evaluation can be quick, easy, and accurate for professionals, comfortable for patients, and highly reproducible. There is high intra-observer correlation between clinical and device measurements. Edema assessment can be quantitative within 1 mm or greater precision. Assessment of edema in semi-quantitative terms is no longer acceptable. It should be discouraged in current medical and nursing practice and shunned in medical and nursing education.

Future studies will explore inter-observer variation in edema assessment.

Declarations

Author contributions:

The author is solely responsible for the creation of the edema depth tester, the collection, integrity, and analysis of the data, and is the sole author of the manuscript.

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Conflicts of Interest

The author has no conflicts of interest to report.

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Figures

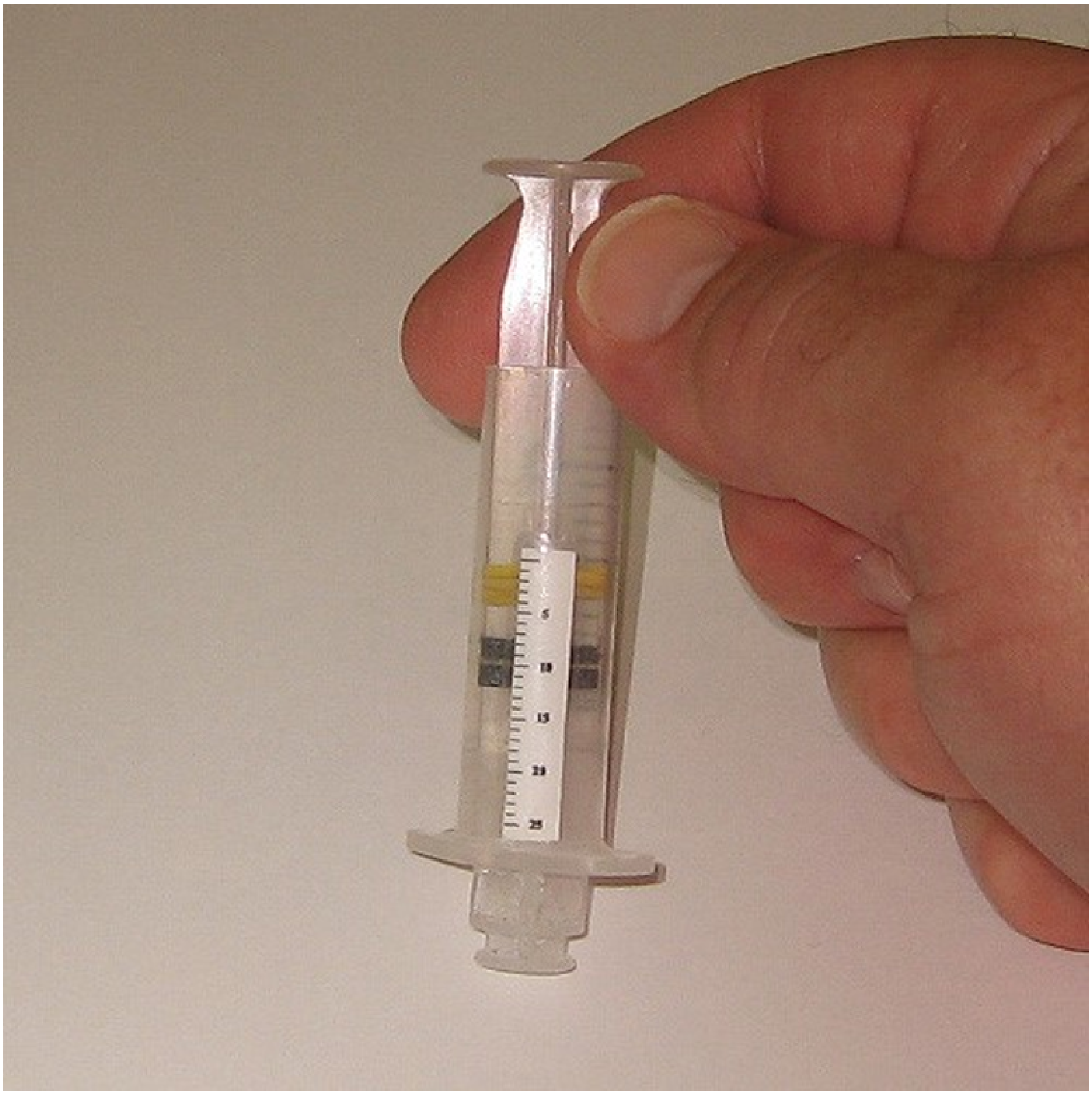


Figure 1

Edema depth testing device. The scale is in millimeters.

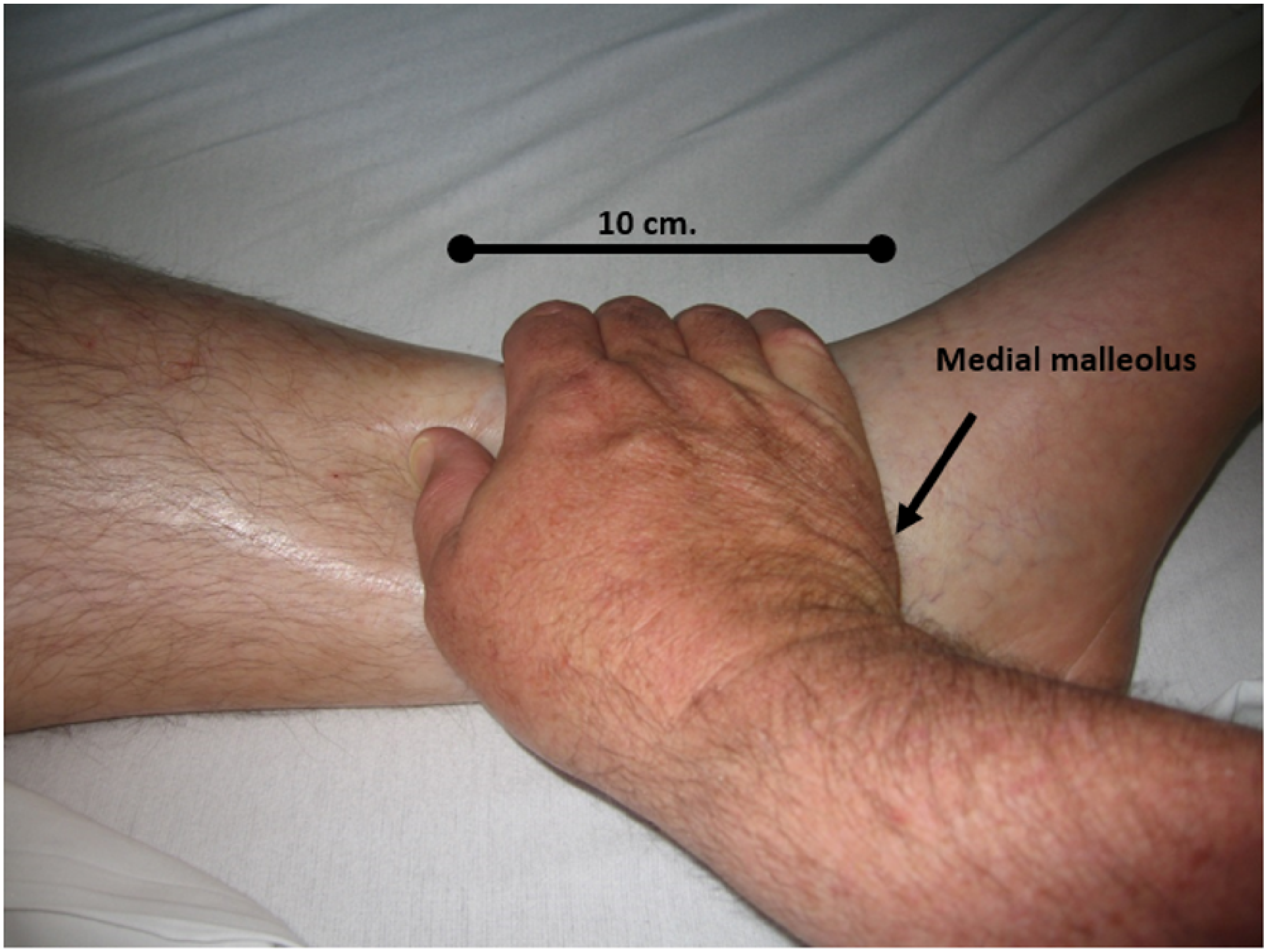


Figure 2

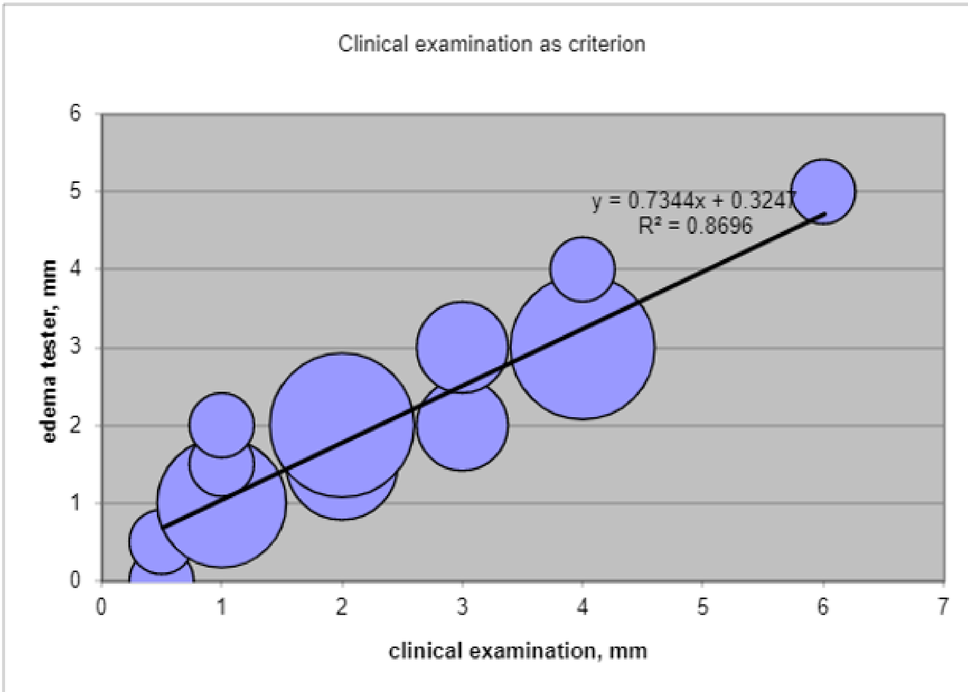
A standard anatomic location for clinical estimation of edema, 10 cm above the medial malleolus, followed by gentle thumb pressure down to the medial tibial ridge.

Figure 3

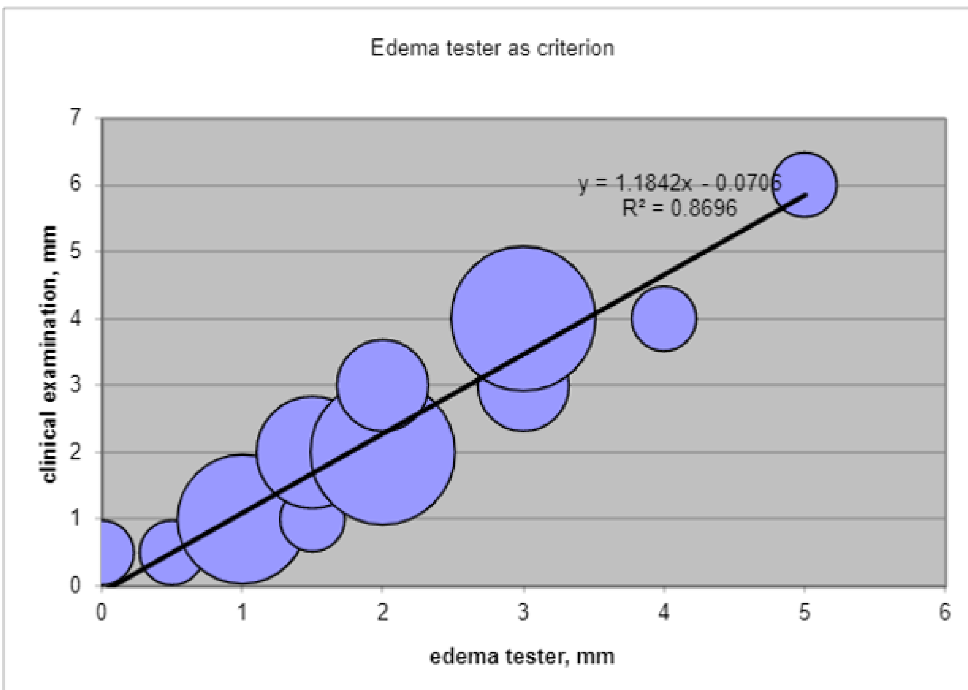
Clinical estimation of pit depth. The examiner has placed the index finger at the bottom of the indented skin, placed the thumb perpendicular to the index finger while resting on the surrounding, unpitted skin. The examiner’s hand is angled to reveal the estimated depth.

Figure 4

The flange of the testing device rests on the unpitted skin while the examiner presses down on the plunger until it rests at the bottom of the indentation. The depth of edema can then be read off the scale.



5a



5b

Figure 5

5a and 5b. Bland-Altman graphs of correlation between clinical and edema tester measurements, using clinical (5a) or edema tester (5b) as criterion standard.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Edemadatasupplementary.xlsx