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Unicornuate uterus: 2D ultrasound, 3D ultrasound, 3D Virtual Model, and Virtual Navigation Findings

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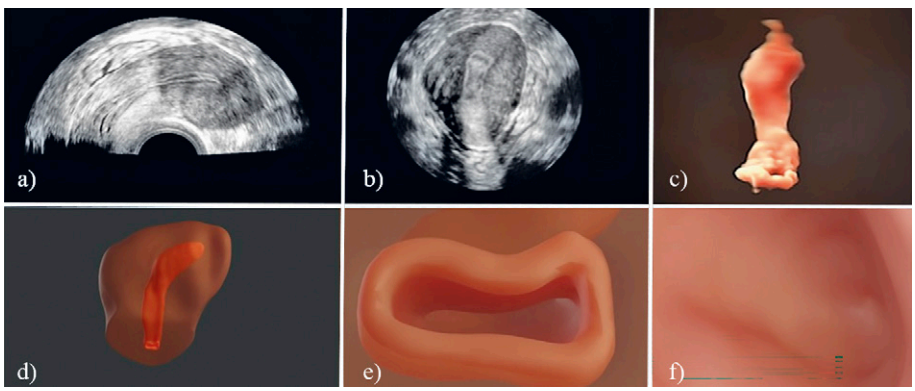

Fig 1. Transvaginal ultrasound 2D and 3D demonstrating a unicornuate uterus. Sagittal view (a), coronal view (b), 3D ultrasound reconstruction (c), and coronal reconstructed image after segmentation of the ultrasound-acquired volume (d), axial view (e), and virtual navigation (f).

To the Editor

The unicornuate uterus is caused by the arrested development of one of the Müllerian ducts and the most common consequences are pelvic pain, hematometra, and endometriosis [1]. Furthermore, unicornuate uterus is associated with averse perinatal outcomes such as lower live-birth, miscarriages, ectopic pregnancies, preterm birth, and cesarean section [2]. Three-dimensional (3D) ultrasound (US) has been good agreement with magnetic resonance imaging (MRI) in the diagnosis of Müllerian duct anomalies [3]. Virtual Navigation (VN) results from a technology that uses software generated realistic images to replicate the immersive feeling of a real environment [4].

An US examination was performed using a transvaginal probe (Voluson E10, RIC-D volumetric probe, 6–12 MHz; GE Healthcare, Zipf, Austria). The stored 3D images were reevaluated using 4DView software and exported in NRRD format. The workflow begins by importing the NRRD files from the selected examination for segmentation. Using 3DSlicer software (v5.1, Birmingham, UK), 3D reconstructions were generated based on the ultrasound data. The uterus and endometrium were individually segmented using the Segment Editor module and subsequently converted into STL files. These files were imported into Blender, where textures such as colors, transparency effects, and lighting were applied. The virtual camera path was created using Blender's ani-

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mation module. Finally, the rendering process generates sequential navigation images, which are saved in video format (fig 1, Video S1 on the journal site).

To the best of our knowledge, this is the first description of NV in a unicornuate uterus. VN has been used to study some fetal congenital anomalies and provides a realistic view of anatomy and 3D spatial relationships with adjacent structures [5]. In this case, VN enabled visualization of the endocervix and the entire uterine cavity up to the tubal ostia. VN can be used as an adjunctive, noninvasive technique to evaluate the uterine cavity in cases of Müllerian duct anomalies, such as for diagnosis and preoperative planning.

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Video S1. Virtual navigation across the endocervix and uterine cavity in a case of unicornuate uterus.

The effectiveness of optic nerve sheath diameter in predicting large vessel occlusion in ischemic stroke patients

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To the Editor,

We have read with great interest the article titled *"The effectiveness of optic nerve sheath diameter in predicting large vessel occlusion in ischemic stroke patients"* [1] recently published in Med Ultrason. Early diagnosis of ischemic stroke due to large vessel occlusion (LVO) is critically important to identify patients who may benefit from urgent reperfusion therapies and to anticipate and proactively manage the high risk of serious complications, such as malignant cerebral edema [2]. Since optic nerve sheath diameter (ONSD) measurement via ultrasound is a rapid and non-invasive method to estimate intracranial pressure (ICP) [3], we agree with the authors that it may support better triage of acute stroke patients.

That said, we would like to highlight several important considerations.

First, malignant cerebral edema does not occur in all patients with hemispheric stroke; it typically affects only 10–30% of them [2)] Furthermore, this condition generally develops between days 1 and 3 post-stroke and is uncommon within the first 24 hours [2]. Therefore, a single ONSD measurement within the first 24 hours may not be a reliable method to determine which patients require urgent reperfusion treatment, as it could fail to identify LVO patients who have not yet developed malignant cerebral edema. This is also evident in the present study: although there were statistically significant differences in median ONSD between the two groups, a large proportion of LVO patients had ONSD values similar to those without LVO [1].

Currently, treatment of malignant cerebral edema is often initiated late, after the condition has fully devel-

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oped. Interventions such as osmotic diuretics and hypertonic saline carry potential serious adverse effects (including renal injury and electrolyte imbalances), and although decompressive craniectomy can reduce mortality, many survivors are left with severe disability [4]. A retrospective observational study involving patients with acute anterior circulation ischemic stroke with extensive ischemia and NIHSS scores ≥15 found that an early increase in the rate of change in the ONSD/globe transverse diameter ratio measured by computed tomography (CT) on day 1 compared to baseline might predict malignant progression [5]. Another study reported that changes in the ONSD/globe diameter ratio may be more predictive than changes in ONSD alone as measured by CT [6]. Additionally, ultrasound-based studies have shown that dynamic changes in ONSD – rather than a single static value – are predictive of raised ICP, with high sensitivity and specificity [5]. Given that ultrasound is a practical tool for serial monitoring – especially in critically ill patients with limited access to CT – it could play a valuable role in identifying patients at risk of malignant cerebral edema before clinical deterioration occurs.

Finally, I would like to highlight that some researchers suggest that, since the optic nerve sheath is not perfectly circular, changes in its cross-sectional area might better reflect volume alterations than diameter alone [3]. In one study comparing different ONSD measurement modalities (longitudinal diameter, vertical diameter, and area) to assess elevated ICP, no significant differences were found in their correlation with ICP values [3].

In any case, I commend the authors for their excellent work. Ocular ultrasound remains largely underutilized among clinicians, and the pursuit of evidence for its clinical application is a meaningful achievement. As a non-invasive, rapid, and relatively harmless technique, it holds promise across a range of conditions associated with elevated ICP. There is a clear need for further studies and structured training programs in this field.

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Giant coronary artery-right atrial fistula with mobile vegetation

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To the Editor,

A 9-year-old boy was admitted with a 2-month history of persistent chest pain and a 9-day febrile episode. Physical examination demonstrated grade III/VI systolic murmur at the cardiac apex. Thoracic computed tomography revealed bilateral pulmonary infiltrates suggestive of infectious etiology. Laboratory investigations showed

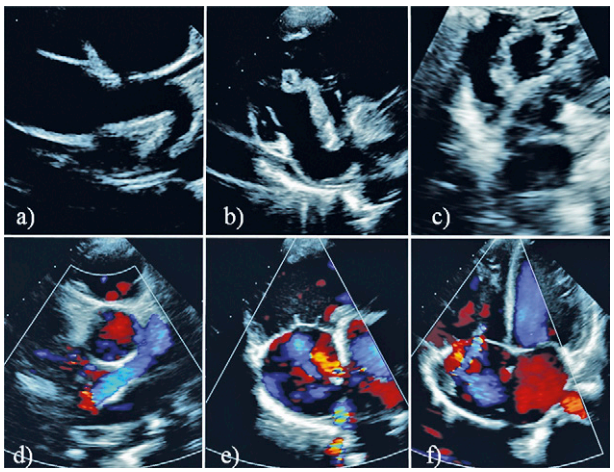

Fig 1. The parasternal short-axis view demonstrated dilatation of the left main coronary artery and circumflex branch (Panel Aa). Four-chamber (b) and subcostal views (c) revealed a mobile mass within the right atrial cavity. Color Doppler imaging showed flow signals within the left coronary artery (d) and turbulent flow at the fistulous orifice (e), with mild to moderate diastolic tricuspid regurgitation. Mild tricuspid valve prolapse with trivial-to-moderate regurgitation (f).

leukocytosis (14.1×10⁹/L) with left shift (20.8% band neutrophils) and markedly elevated high-sensitivity C-reactive protein (46.61 mg/L). Transthoracic echocardiography (TTE) identified the following key findings: 1. Dilation of the left main coronary artery and its circumflex branch (fig 1a), forming a fistulous connection to the right atrium; 2. A mobile, pedunculated mass (45.7×10.6 mm) adjacent to the coronary vasculature (fig 1b,c), demonstrating phasic motion synchronous with cardiac contraction; 3. Color Doppler visualization of coronary flow (fig 1d) and biphasic high-velocity shunt flow through the fistula (fig 1e), with absence of intralesional vascularity; 4. Mild tricuspid valve prolapse with trivial-to-moderate regurgitation (fig 1f). The spatial relationship between the mass and fistula, coupled with persistent fever, raised suspicion for infective vegetation. Emergency surgical management included fistula closure and mass resection. Histopathological examination confirmed the diagnosis of infective endocarditis, demonstrating necrotic debris with mixed acute-chronic inflammatory infiltrates and bacterial microcolonies.

The clinical presentation of coronary artery fistula (CAF) exhibits substantial heterogeneity, closely correlated with hemodynamic perturbations caused by fistula dimensions and shunt magnitude [1]. While approximately 50% of patients remain clinically silent during initial phases, the emergence of coronary steal syndrome may manifest as classic anginal symptoms, exertional dyspnea, or syncopal episodes [1]. Crucially, CAF carries significant morbidity risks, with documented complications encompassing congestive heart failure, infective endocarditis, aneurysmal rupture, and pulmonary hypertension [2]. The pathogenesis of endocarditis in this context stems from high-velocity turbulent flow at the fistulous communication, generating shear forces that compromise endothelial integrity, thereby establishing a nidus for microbial adherence and biofilm formation [1,2].

From a diagnostic perspective, TTE serves as the cornerstone imaging modality for CAF evaluation, offering noninvasive real-time hemodynamic assessment. Beyond delineating coronary arterial dilatation and tortuous fistulous tracts, TTE facilitates precise ostial localization, and comprehensive evaluation of cardiac chamber remodeling [1]. In our case, TTE not only confirmed the right coronary artery-to-right atrial fistula but also revealed a vegetation, exhibiting independent motion at the drainage site. Considering the elevated embologenic risk associated with such mobile vegetations – particularly the threat of life-threatening systemic embolism – surgical treatment was immediately performed. This involved definitive fistula ligation with concomitant vegetation excision, thereby preventing potential clinical deterioration while addressing both anatomical and infectious sequelae.

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Multiple transient intussusceptions

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To the Editor,

A 7-year-old girl presented with complaints of abdominal pain and sought medical attention. An ultrasound examination was performed, revealing two concentric circular changes measuring 17x17 mm in the intestinal tract below the navel (fig 1). These changes exhibited visible peristalsis and dotted blood flow signals. However, no abnormal echoes were detected in the lower right abdomen. During examination, the concentric circular changes in the intestinal tract spontaneously resolved. Subsequently, the girl's abdominal pain also disappeared. Up to now, no abnormalities have been detected in the follow-up examinations.

Intussusception refers to intestinal obstruction caused by the insertion of a certain segment of the intestine and its corresponding mesentery into the adjacent intestinal cavity. Multiple intussusceptions refer to the separation of two or more intussusceptions in different areas of the intestinal canal, which is relatively rare [1]. Melvin et al study [2], transient and benign small bowel-small bowel intussusception characterized by spontaneous resolution, diameter of less than 2.5 cm, no lead point, normal bowel wall thickness, nondilated proximal small bowel, and no colonic involvement. Intussusception is a frequent cause of abdominal pain and vomiting in infants and children. The majority of pediatric intussusceptions are primary ones, which can be categorized into six types: ileocolic, ileo-ileocolic, colocolic, ileo-colo-colic, ileo-ileal, and jejuno-jejunum. Among them, the ileocolic type is the most prevalent. Based on the number of occurrences,

Fig 1. Ultrasound examination revealing two concentric circular changes in the intestinal tract below the navel.

intussusception can be divided into single and multiple types. Most single intussusceptions are of the ileocolic, ileo-ileocolic, or colocolic type, with a smaller proportion being the ileo-ileal or jejuno-jejunum type [3]. Intussusception ranks as the second most frequent cause of acute abdomen in children, following appendicitis. Roughly 60% of pediatric intussusception cases occur in children under one year of age, and 80% to 90% happen in those under the age of two. In infants aged 9–24 months, it is typically primary. However, in children older than 3 years, there is a higher likelihood of an underlying specific lead point being present. Common lead points may encompass Meckel's diverticulum, polyps, IgA vasculitis, and recent adenovirus infection [4].

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A case of rare primary thyroid leiomyosarcoma diagnosed by ultrasound

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To the Editor,

A 69-year-old male presented with a left thyroid mass discovered during a routine physical examination three months earlier. Ultrasound imaging identified a solid hypoechoic nodule in the left thyroid lobe, measuring 3.4×4.1 cm, exhibiting a taller-than-wide morphology, irregular borders, and multiple hyperechoic calcifications. Minimal intranodular vascularity was noted (fig 1a). Thyroid function tests were within normal limits. Histopathological analysis of the biopsy confirmed a diagnosis of left thyroid leiomyosarcoma. Subsequent CT scans revealed bilateral pulmonary metastases (fig 1b). Despite undergoing total left thyroidectomy, the patient succumbed to progressive respiratory failure six months postoperatively.

Primary thyroid leiomyosarcoma (LMS) is an exceptionally rare malignancy, accounting for merely 0.014% of all primary thyroid cancers [1]. This mesenchymal-origin tumor arises from smooth muscle cells within the thyroid capsule's vasculature and is notorious for its aggressive behavior and poor prognosis [2].

Although primary thyroid LMS predominantly affects females, this case represents a rare male occurrence. The disease typically manifests in elderly individuals, with a mean age of onset around 65 years. Clinically, patients often present with a rapidly enlarging neck mass.

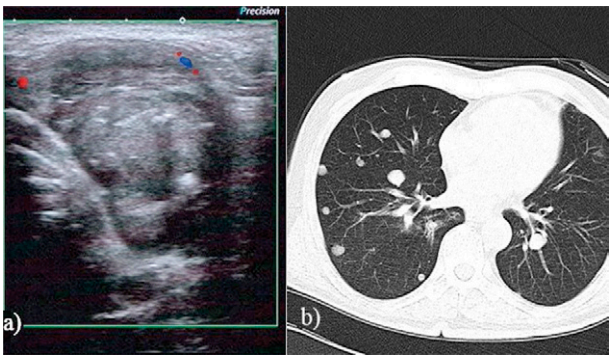

Fig 1. a) The ultrasound examination revealed a solid hypoechoic nodule in the left lobe of the thyroid with a taller-than-wide shape, multiple calcifications, and punctate blood flow signals within it; b) CT showed bilateral pulmonary metastases.

Distant metastases, particularly to the lungs - the most common metastatic site - may lead to symptoms such as fever, cough, and dyspnea. Gastrointestinal involvement can result in weight loss and hematemesis [3]. Treatment modalities include surgical excision, radiotherapy, and chemotherapy. However, due to the tumor's highly aggressive nature, recurrence and distant metastasis frequently occur shortly after surgery. While chemotherapeutic agents may be employed for neoadjuvant cytoreduction or adjuvant therapy, current evidence suggests that neither chemotherapy nor radiotherapy significantly improve survival outcomes in primary thyroid LMS [4].

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Thrombus attached to tricuspid valve chordae tendineae associated with mycoplasma pneumonia

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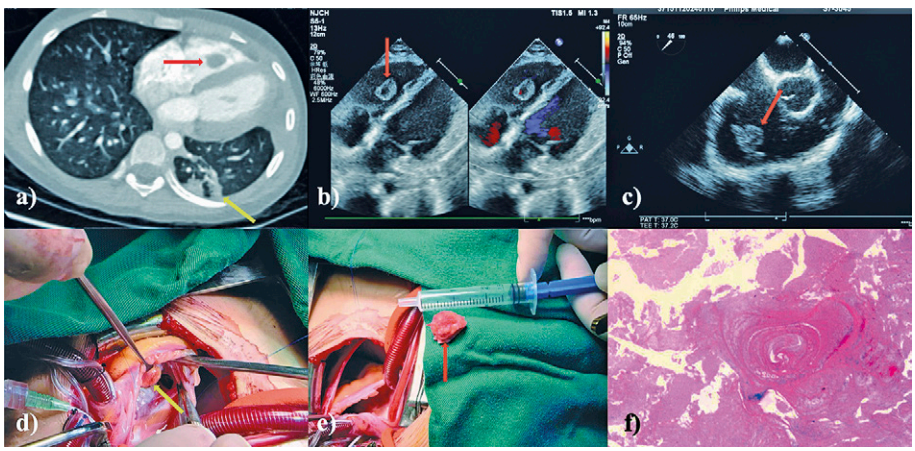

Fig 1. a) The lung computed tomography revealed a consolidation shadow in the left lung lower lobe (yellow arrow) and right ventricular mass (red arrow); b) transthoracic echocardiography showed a mass in the right ventricle; c) intraoperative transthoracic echocardiography showed the mass attached to the tricuspid valve chordae tendineae; d) surgical exploration revealed the mass attached to the tricuspid valve chordae tendineae; e) the mass was removed completely without damaging the tricuspid valve; f) pathological examination confirmed that the mass shadow was a relatively new fibrin thrombus with fewer white blood cells.

To the Editor,

A healthy 8-year-old girl was referred to the emergency department for 5 days of high fever and violent coughing. No hemoptysis, fatigue, or syncope were present in this period. Blood cultures showed mycoplasma pneumonia in the local hospital. Despite intravenous administration of ceftriaxone (80 mg/kg/day) and azithromycin (10 mg/kg/day) for 3 days in the local hospital, fever and respiratory status continued to deteriorate. A pulmonary computed tomography (CT) in our center revealed a consolidation shadow in the left lung lower lobe and right ventricular mass (fig 1a). Transthoracic echocardiography confirmed the mass echoes in the right ventricle (fig 1b). Coagulation analysis revealed elevated D-dimer levels (11 mg/L; normal reference range, 0–0.55 mg/L) and fibrinogen (FIB) (6.88 g/L; normal reference values, 2–4 g/L). Based on these findings, cardiac thrombus was suspected.

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Because it was difficult to determine the nature of the mass in the cardiac, and the large mass was floating in the tricuspid chordae tendineae, an emergency operation was conducted to diagnose and treat diseases. Intraoperative transesophageal echocardiography showed the mass attached to the tricuspid valve chordae tendineae (fig 1c). Surgical exploration revealed the mass attached to the tricuspid valve chordae tendineae in the right ventricle (fig 1d). The mass was removed completely without damaging the tricuspid valve (fig 1e). Pathological examination confirmed that the mass was a relatively new fibrin thrombus with fewer white blood cells (fig 1f). Following 14 days of hospitalization, the patient was discharged and continued with low molecular weight heparin calcium and aspirin. On follow-up six months later, echocardiography showed no new cardiac thrombosis.

Vascular complications are among the rarest extrapulmonary manifestations of mycoplasma pneumoniae infection, with children exhibiting heightened susceptibility [1-3]. The main treatments of mycoplasma pneumonia complicated with intracardiac thrombus include anticoagulation therapy, thrombolytic therapy, and surgical thrombectomy. Given the risk of the large mass floating on the tricuspid valve chordae tendineae potentially dislodging and causing acute pulmonary embolism, we proceeded with emergency surgery.

In the course of diagnosis and treatment of mycoplasma pneumonia infection, the occurrence of thrombus in the heart cavity should be noted. Based on available clinical literature, we believe that anticoagulant therapy for small intracardiac thrombosis is an effective method and relatively safe with low molecular weight heparin. Surgical thrombectomy may be an appropriate treatment for large unstable thrombus.

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Horns of the ram and wings of the seagull: ‘sono-story’ for medial meniscopathy

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To the Editor,

Ultrasound (US) is widely utilized in the evaluation of innumerable musculoskeletal disorders [1]. Despite its several advantages (easily accessible, cost-effective, radiation-free etc.), user-dependency poses some limitation. As such, US training is crucial and has been a major focus in the recent musculoskeletal literature. With the developing technology, there are attempts for easier education also incorporating ‘entertainment’. For instance, metaphorically associating US findings with images taken from the nature, animals, or various objects is such an effective way [2,3].

Likewise, US findings of a 59-year-old female patient with right knee pain are rendered in this report. The appearance of medial meniscal bulging in between the femoral and tibial osteophytes is described to look like the head/horns of a ram or the wings of seagull (Video, on the journal site). We believe that this metaphorical depiction will aid in the memorability of a common condition, i.e. medial meniscopathy, which can readily/promptly be diagnosed and targeted using US.

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Video legend

Ultrasound examination for the medial knee joint in long-axis view, femur (*F*), tibia (*T*), femoral and tibial osteophytes (*stars*), medial colletarel ligament (*arrow heads*), medial meniscus (*mm*). During sono-palpation of the most painful area(s), the femoral and tibial osteophytes were prominent on both sides of the bulging medial meniscus. As the ultrasound transducer is moved from anterior to posterior, and depending the convexity of the hyperechoic cortical irregularities, the horns of a ram or the wings of a seagull can be imagined.

A game changer in orofacial pain: ultrasound-guided dry needling of the digastric muscle

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To the Editor,

Myofascial pain syndrome (MPS) is an important cause of chronic musculoskeletal pain; however, certain muscles like digastric muscle often receive little attention in the clinical practice. The digastric muscle, a critical muscle in the suprahyoid musculature, is important for mandibular movement and swallowing. Myofascial trigger points in this muscle are often overlooked as contributors to neck and jaw pain, leading to misdiagnosis and ineffective treatment despite their clinical importance [1].

The digastric muscle consists of two separate bellies, the anterior belly (originating from the mandible) and the posterior belly (originating from the mastoid process). These bellies are connected by an intermediate tendon, contributing to complex functional interactions with the temporomandibular joint, cervical spine, and oropharyngeal structures. Trigger points in this muscles may produce referred pain patterns that can mimic as temporomandibular disorder (chronic jaw pain) or dental pathologies, which cause misdiagnosis and a delay in the correct treatment [2]. Previous research by Simons et al. has emphasized the clinical relevance of trigger points

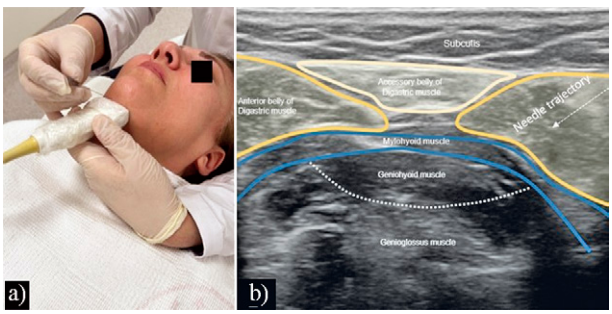

Fig 1. Image shows the patient's head in slight extension and the physician standing behind the patient (a). It demonstrates dry needling of the digastric muscle using an in-plane approach (b).

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in this muscle; however, its role in orofacial pain syndromes remains underappreciated [1].

Given these challenges, dry needling has emerged as a promising intervention for MPS, as it targets trigger points and inactivates them, providing patients with localized relief. Due to anatomical localization and proximity of neurovascular structure, ultrasound-guided dry needling is recommended to enhance both safety and efficacy. The patient's head position should be placed in mild extension and contralateral head rotation to facilitate muscle identification between the hyoid bone and mandible (fig 1a). Although both in-plane and out-of-plane techniques can be used, in this article the in-plane approach is presented. In this method, the needle (acupuncture needle – 0.3 × 30 mm) is positioned parallel to the long axis of the transducer, enabling direct visualization of the entire needle path and allowing real-time monitoring of tissue movement and twitch response. Clinical evidence suggests that once a week and a total of three sessions can effectively reduce pain and restore function [3]. However, further randomized controlled trials are necessary to refine treatment protocols and establish long-term efficacy.

To the best of our knowledge, this is the first documented method incorporating ultrasound-guided dry needling of the digastric muscle, setting it apart from blind techniques. Adopting this technique may improve precision and safety, resulting in more effective treatment outcomes for patients with myofascial pain syndrome involving the digastric muscle.

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A rare case of primary urachal inflammatory myofibroblastic tumor

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To the Editor,

A 38-year-old female patient underwent ultrasonography during the second trimester of pregnancy due to a lower abdominal mass accompanied by discomfort. The ultrasound revealed a solid mass at the junction of the urachus and the anterior wall of the bladder (fig 1A), with indistinct borders. The mass had rich arteriovenous blood flow signals (fig 1B). The ultrasound diagnosis was considered to be a urachal mass and cystoscopic biopsy indicated papillomatous changes in the bladder mucosa. Conservative treatment was temporarily decided.

Fifty days after a spontaneous vaginal delivery, the patient returned to our hospital for a follow-up examination. Enhanced CT revealed a nodular soft-tissue density shadow on the anterior wall of the bladder protruding into the bladder lumen, with mild enhancement in both arterial and venous phases (fig 1C,D). The diagnosis was a tumorous lesion on the anterior wall of the bladder. Subsequent cystoscopy indicated a 2.0 cm protruding lesion on the anterior wall of the bladder dome. Based on the patient's clinical manifestations and various imaging findings, the final diagnosis was urachal cancer and extended partial cystectomy was performed laparoscopically. The pathological specimen showed a grayish-

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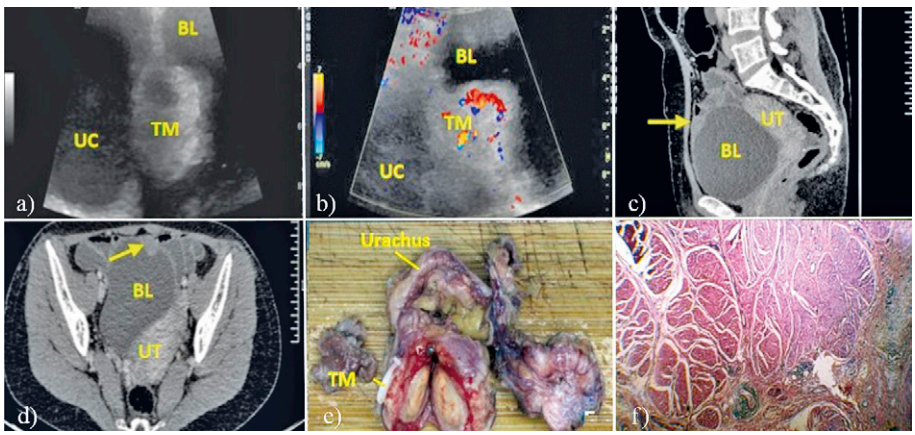

Fig 1. a) Two-dimensional ultrasound reveals a solid mass at the junction of the urachus and the anterior wall of the bladder, with wide base and irregular shape, indistinctly delineated from the bladder wall and the lower anterior segment of the uterine wall; b) Color Doppler ultrasound showed abundant arteriovenous blood flow signals in the tumor; c) and d) Enhanced CT revealed a nodular soft-tissue density shadow on the anterior wall of the bladder protruding into the bladder lumen, with mild enhancement in both arterial and venous phases; e) The pathological specimen showed a grayish-yellow solid nodular tissue on the cut surface; f) Microscopically, the lesion was composed of a mixture of spindle-shaped myofibroblasts, fibroblasts, and a large number of plasma cells, lymphocytes, histiocytes, and a few eosinophils, infiltrating the striated muscle tissue and enveloping the urachal tissue. UC: Uterine Cavity; BL: Bladder; TM: Tumor; UT: Uterus

yellow solid nodular tissue on the cut surface (fig 1E). Microscopically, the lesion was composed of a mixture of spindle-shaped myofibroblasts, fibroblasts, and a large number of plasma cells, lymphocytes, histiocytes, and a few eosinophils, infiltrating the striated muscle tissue and enveloping the urachal tissue (fig 1F). The histopathological diagnosis was Inflammatory myofibroblastoma (IMT) of the urachus. Postoperatively, the patient underwent chemotherapy with intravesical instillation of hydroxycamptothecin. Follow-up has shown no recurrence or metastasis of the tumor.

IMT is a rare mesenchymal-derived tumor with low-grade malignancy and borderline characteristics, predominantly occurring in children and most frequently localized in the lungs, abdomen, or pelvic cavity. Invasion of the urachus is extremely rare [1]. This tumor is characterized by proliferating spindle cells with differentiated myofibroblastic features, inflammatory cell infiltration, and myxoid degeneration [2]. In this case, the patient was a young female with a primary tumor originating from the urachus, which is infrequently reported.

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Comment to: “Enhancing sonologist examination performance with large language models: an analytical study of ChatGPT-4 and Claude 3”

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To the Editor,

The publication on “Enhancing sonologist examination performance with large language models: an analytical study of ChatGPT-4 and Claude 3 [1]” is hereby discussed. Although this study raises interesting questions about the use of large language models (LLMs) such as ChatGPT-4 and Claude 3 to improve the question-answering accuracy of ultrasound physicians at various levels, the study design has significant limitations, particularly the very small sample size (only one person per level of experience), which prevents true statistical analysis and generalization of the results to the target population.

Although p-values are presented to show significant differences, the absence of other essential statistical parameters such as means, standard deviations, and effect sizes makes the results difficult to understand. Furthermore, depending merely on p-values to establish if a change is “significant” may not be adequate for assessing its educational value, particularly in contexts with fewer participants.

A question that should spark additional discussion at the professional level is, “What kind of teaching tool should LLM models be used as - to review knowledge or to adjust physicians’ clinical thinking?” in “If model explanations only partially improve scores, should models be developed for contextual understanding or simplification?”. It is also vital to consider the impact of model dependency on long-term training on trainees’ critical thinking skills.

To make this research more original and effective in practice, the sample size should be increased to include physicians with a variety of expertise levels, as well as genuine clinical scenarios, such as offering LLM assistance during real-time ultrasound diagnostic. Another way is to compare the model’s performance under various situations, such as question complexity or response time, in order to clearly highlight the model’s strengths and limitations in each scenario.

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Author's response

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We read with great interest the Letter to the Editor and we would like to sincerely thank the readers for their thoughtful and constructive comments.

We appreciate the critical point raised concerning the sample size in our study. Indeed, this was designed as a preliminary, exploratory study aiming to evaluate the potential of LLMs in assisting sonologists at different experience levels. We fully recognize the limitations inherent in a small sample, as also acknowledged in our discussion. Moving forward, we plan to expand the sample size, involving a broader range of sonologists with varying levels of expertise, to enhance the representativeness and generalizability of our findings.

Regarding the statistical analysis, we acknowledge the concern about the presentation of results. As our study focused on dichotomous outcomes (correct vs. incorrect answers), we applied *Chi-square* tests without reporting means, standard deviations, or effect sizes, which are not applicable in this binary outcome context. Nevertheless, we agree that beyond p-values, future studies could benefit from incorporating other descriptive statistics and effect size metrics where appropriate, especially with larger datasets, to improve the interpretability and robustness of the results.

Furthermore, we appreciate the readers' distinction between statistical significance and educational value. While the observed p-values in our study indicate a potential effect of LLMs on improving answer accuracy, we fully recognize that statistical significance alone does not sufficiently reflect the practical educational impact of such tools. Future research will place greater emphasis on evaluating actual learning outcomes, depth of knowledge acquisition, and the subjective learning experiences of sonologists when using LLMs for educational support.

We also acknowledge the important issue raised regarding model dependency and its potential influence on clinical reasoning. We agree that LLMs should be considered as assistive tools rather than substitutes for clinicians' critical thinking and decision-making processes. Our study primarily focused on their role in knowledge reinforcement and self-assessment. However, we intend to incorporate longitudinal follow-up studies and cognitive impact evaluations in future research to thoroughly explore the long-term effects of LLM use in medical education and clinical practice.

Finally, we concur with the suggestions for future research directions, including integrating LLMs into real clinical scenarios, evaluating their performance across different levels of question complexity, and assessing the impact of response time constraints. These valuable considerations will indeed guide our subsequent investigations.