• Clinical Research •

Investigation of lacrimal sac space-occupying lesions using color doppler ultrasound, computed tomography, and computed tomography dacryocystography

Zhen–Bin Qian[1], Bo Yu[1], Ye Yang[1], Wei Fang[1], Jian–Li Dong[2], Li–Qing Wei[1]

[1]National Clinical Research Center for Ocular Diseases, Eye Hospital, Wenzhou Medical University, Wenzhou 325027, Zhejiang Province, China

[2]Sijiqing Street Community Health Service Center, Hangzhou 310000, Zhejiang Province, China

Correspondence to: Li-Qing Wei. Eye Hospital of Wenzhou Medical University, 270 West Xueyuan Road, Wenzhou 325027, Zhejiang Province, China. weiliqing@wmu.edu.cn

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Abstract

● **AIM:** To observe the imaging features of color Doppler ultrasound (CDU) and computed tomography (CT) or computed tomography dacryocystography (CT-DCG) in different types of lacrimal sac space-occupying lesions (SOLs).

● **METHODS:** This retrospective case series study included 21 patients with lacrimal sac SOLs who underwent lacrimal sac surgery between January 2018 and March 2022. The imaging features of CDU and CT or CT-DCG in these patients were extracted from the examination cloud system. The images were observed and analyzed.

● **RESULTS:** The detection rate of lacrimal SOLs between CDU (21/21, 100%) and CT or CT-DCG (20/21, 95.2%) had no statistically significant difference (P=1.0). CDU could detect the blood flow signals in all SOLs except mucocele and mucopeptide concretion. Among them, polyps had characteristic imaging changes on CDU and CT-DCG. The mucoceles and mucopeptide concretions had characteristic imaging changes on CDU, which could provide more information for differential diagnosis.

● **CONCLUSION:** The morphology and internal blood flow signals of lacrimal sac SOLs can be observed using CDU. CT or CT-DCG has advantages in observing structural damage around the lacrimal sac mass. Therefore, CDU may be used as a routine examination to exclude lacrimal sac SOLs before dacryocystorhinostomy in the absence of preoperative CT or CT-DCG.

● **KEYWORDS:** lacrimal sac; computed tomography; computed tomography dacryocystography; color Doppler ultrasound; space-occupying lesions

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INTRODUCTION

Dacryocystitis and nasolacrimal duct obstruction are fairly common disorders in adults and are the common causes of epiphora. Dacryocystorhinostomy (DCR) is a widely used and effective treatment for such conditions. In some cases, space-occupying lesions (SOLs), such as mucopeptide concretions, mucoceles, granulomas, and even tumors[1-4] can be found in the lacrimal sac area. DCR can be performed without issue in patients with mucopeptide concretions, mucoceles, and granulomas[1,3]. However, a more complex treatment plan must be adopted for patients with lacrimal sac tumors. It is important to inform patients about the severity of their condition and the complexity of the treatment prior to surgery, as more than 55% of lacrimal sac tumors are malignant[4-7]. Thus, preoperative diagnosis and identification of lacrimal sac SOLs are essential.

A computed tomography dacryocystography (CT-DCG) of the lacrimal drainage system is always considered effective in recognizing lacrimal sac SOLs, mainly manifesting as lacrimal sac filling defects[4-5]. Computed tomography (CT) is also an important and commonly used method in diagnosing such lesions[8-10]. However, a previous study reported that the proportion of patients completed CT examinations before DCR was less than 5%[11]. Therefore, due to a lack of imaging examinations and the symptoms similarities dacryocystitis and nasolacrimal duct obstruction, lacrimal sac SOLs are often not identified before DCR[5-6,8-9,12-14]. Color Doppler ultrasound (CDU) applied in lacrimal system diseases can clearly show the two-dimensional structures of the lacrimal sac and surrounding tissues with normal and abnormal blood flow conditions[15-16]. Additionally, CDU has been used to observe lacrimal gland tumors[17]. Furthermore, CDU has the advantages of being radiation-free, easy to operate, and economical. Thus, CDU may become an important tool in detecting lacrimal sac SOLs. However, no study has yet been conducted on the color Doppler imaging changes of such SOLs. Therefore, this study was carried out to assess the CDU and CT-DCG characteristics of the lacrimal sac SOLs.

SUBJECTS AND METHODS

Ethical Approval The study protocol adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Wenzhou Medical University (Approval number: H2022-018-k-18-01). The institute ethics committee waived the informed consent for extracting data from hospital records while ensuring that the personal identities of the participants were not revealed.

Patients A total of 33 patients with lacrimal sac SOLs were found in the Eye and Optometry Hospital Affiliated with Wenzhou Medical University database from January 2018 to March 2022. However, preoperative CDU or CT examination was absent in 12 of them. Finally, 21 patients were included in this study. Lacrimal sac SOLs were diagnosed through intraoperative findings and pathological examination. The basic information of all patients, including age, sex, side of involvement, duration of epiphora, and history of lacrimal system intervention was recorded. All the SOLs obtained during surgery were sent for pathological examination.

Preoperative Examination All patients completed CDU and CT-DCG or CT examination two weeks prior to surgery. CDU was performed using the Vinno G60 system (Vinno Technology, Suzhou, China) with an electronic linear probe of a central frequency of 16 MHz. All patients were examined in the supine position. First, the skin in the lacrimal fossa region was coated with a disinfectant coupling agent. Then, the probe was placed over the skin and moved in transverse and cranio-caudal directions. A qualitative assessment of the size of the lacrimal sac, its content, and surrounding structures was done in B-mode (frequency 16 MHz). The CDU (frequency 10 MHz) was subsequently used to analyze the presence of blood supply in the lacrimal sac SOLs. Further, a water-soluble iodinated contrast medium (compound maglumine diatrizoate, 370 mg/mL) was injected through the lower lacrimal punctum to acquire CT-DCG images. The layer thickness of CT and CT-DCG was 0.5, 1 mm.

Statistical Analysis The IBM SPSS Statistics (version 26, USA) software was used for the statistical analysis. The statistical description was applied to the clinical and demographic characteristics of patients, and Fisher's exact test was used to compare the detection rates of lacrimal SOLs between CDU and CT or CT-DCG. A P value less than 0.05 was considered significant.

Table 1 Clinical and demographic characteristics of patients

Parameters	Values
Age (y)	53.2±14.3 (28–82)
Disease duration, mo (range)	29.8±23.4 (2–108)
Follow up, mo (range)	9.6±4.5 (1–23)
Right eye:left eye	9:12
Male:female ratio	4:17

RESULTS

According to intraoperative and pathological findings, eight lacrimal sac polyps, six mucoceles, three mucopeptide concretions, one inflammatory granuloma with mucopeptide concretion, one inflammatory granuloma, and two tumors were detected among the 21 lacrimal sac SOLs. The basic information of all patients is presented in Table 1. The CDU showed abnormal lacrimal sac imaging in all cases of SOLs (21/21, 100%), while CT or CT-DCG showed abnormal imaging in 20 cases (20/21, 95.2%). No statistically significant difference was observed between the two (P=1.0). The CDU imaging features of different types of lacrimal sac SOLs are summarized in Table 2. All patients underwent endoscopic endonasal DCR, except for two cases of tumor and one case of inflammatory granuloma. Eighteen cases underwent endoscopic endonasal DCR were successful, with none recurring after surgery. The patient with melanocytic carcinoma was followed up for one month without recurrence. However, the patient lost the follow-up. The patient with squamous cell carcinoma showed no recurrence during the nine-month follow-up.

The results of conventional ultrasonography of 8 cases of lacrimal sac polyps showed moderate-signal, echogenic, solid masses in the lacrimal sac. In all 8 cases (8/8, 100%), the masses were round-like with clear, smooth edges and a uniform internal echo (Figure 1A). Additionally, the base of the mass connecting to the lacrimal sac wall was narrow in all cases (Figure 1A). Furthermore, CDU revealed that 7 out of 8 patients (7/8, 87.5%) had lined or dotted blood flow signals inside the SOLs (Figure 1B). Meanwhile, no blood flow signal was detected in 1 case (1/8, 12.5%) due to the small mass (the largest cross-section was about 1.5×1 mm^2). CT-DCG demonstrated a solid mass of soft tissue density in the lacrimal sac. In the 7 cases (7/8, 87.5%), a round-like filling defect connected to the lacrimal sac wall was observed (Figure 1C). However, no filling defect was seen in the other case (1/8, 12.5%) because of the small mass. During surgery, smooth-surfaced spherical-like soft tissue was found in the lacrimal sac of all 8 patients (Figure 1D).

Conventional ultrasonography of 6 cases of mucoceles revealed moderate-intensity, flocculation echoes in the lacrimal sac. Out of the 6 cases, 4 (4/6, 66.7%) resembled an oval

Table 2 The CDU imaging features of different types of lacrimal sac SOLs

Diagnose	No. of cases	Edge	Morphology	Signal and internal echo	Location	Blood flow signal
Polyp	8	Clear and smooth (8/8)	Round-like shape (8/8)	Moderate signal echo, the internal echo was uniform (8/8)	Base of mass connected to wall of lacrimal sac was narrow (8/8)	7 patients (7/8) had blood flow signal inside, 1 case (1/8) showed no blood flow signal due to the small mass
Mucocele	6	N/A	4 cases (4/6) resembled an oval shape, and 2 cases (2/6) had a "hill"-like shape, narrow in the upper part and wide in the lower part	Moderate-intensity flocculation echoes, which gradually increased from top to bottom, and the echoes of the posterior wall of sac were significantly enhanced	The base of the echo is widely connected to the lacrimal sac	No blood flow signal was detected in all patients
Mucopeptide concretion	3	Clear not smooth (3/3)	Oval-like shape (3/3)	Moderate-high signal echo, uneven internal echoes, 2 cases (2/3, 66.7%) had echo attenuation	2 cases (2/3) of large concretions were attached to the wall of the lacrimal sac, while the case of small concretion was not	No blood flow signal was detected in all patients
Inflammatory granuloma	1	Clear not smooth	Irregular shape	Moderate-high signal echo, uneven internal echoes	Base adhering to sac wall	Abundant blood flow signals
Inflammatory granuloma with concretion	1	Unclear	Irregular shape	Moderate-high signal echo, uneven internal echoes	Base was connected to lacrimal sac	Speckled blood flow near the sac wall
Tumor	2	1 case (1/2) had a clear border, 1 case (1/2) the boundary was unclear	Filled the entire lacrimal sac	Uneven internal echoes (2/2)	Base of the tumor was widely attached to sac wall in 1 case, while the base could not be observed in the other case	Scattered punctate blood flow signals in melanocytic carcinomas, while more abundant blood flow signals in squamous cell carcinomas

CDU: Color Doppler ultrasound; SOLs: Space-occupying lesions; N/A: Not applicable.

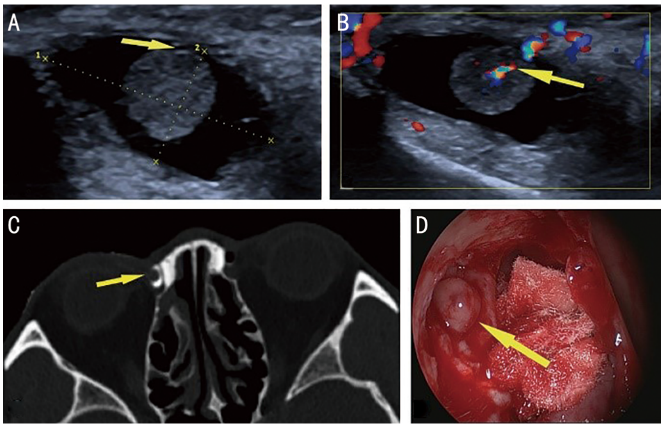

Figure 1 Imaging features of polyps in CDU and CT-DCG A: A round-like with uniform internal echo and a clear margin was detected during the conventional ultrasound. The yellow arrow shows the narrow connection between the base of mass and the wall of the lacrimal sac. B: CDU showed lined blood flow signal inside of mass. C: CT-DCG showed a round filling defect of soft tissue density connected to the lacrimal sac wall (yellow arrow). D: Smooth-surfaced, spherical-like soft tissue found during surgery (yellow arrow). CDU: Color Doppler ultrasound; CT-DCG: Computed tomography dacryocystography.

shape, while the other 2 (2/6, 33.3%) had a "hill"-like shape, which was narrow at the top and wide at the bottom (Figure 2A, 2B). Furthermore, the echoes gradually increased from top to bottom, appearing similar to "precipitation". Additionally, the echoes on the posterior wall of the lacrimal sac were significantly enhanced (Figure 2A, 2B). Moreover, CDU showed that there was no blood flow signal in the lacrimal sac in all 6 patients (6/6, 100%; Figure 2C). CT scans revealed a low-density soft tissue mass in the lacrimal sac (Figure 2D). During surgery, no solid mass was found in any patient.

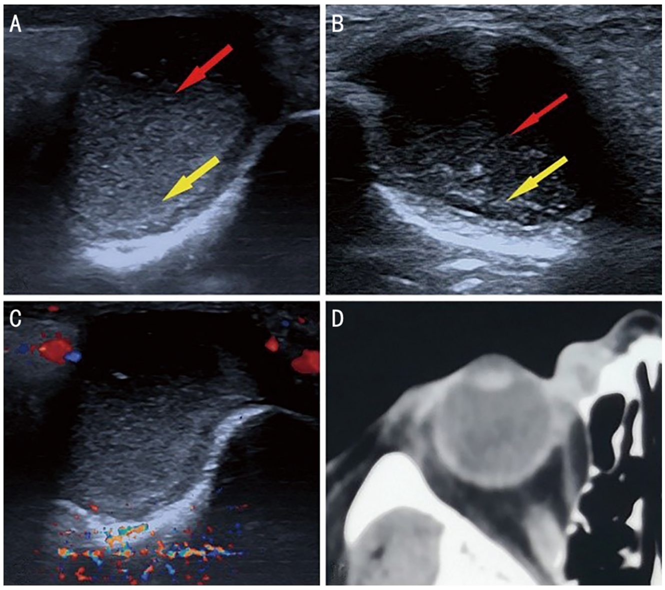

Figure 2 Imaging features of mucoceles in CDU and CT-DCG A and B: An oval shape and a "hill"-like shape with moderate-intensity flocculation echoes, which gradually increased from top to bottom. The echoes of the posterior wall of the lacrimal sac were significantly enhanced as detected in conventional ultrasound. The red arrow showed top echoes, and the yellow arrow showed bottom echoes. C: CDU showed no blood flow signal inside of mass; D: CT showed soft tissue mass in the lacrimal sac without obvious bone destruction. CDU: Color Doppler ultrasound; CT-DCG: Computed tomography dacryocystography; CT: Computed tomography.

Moreover, the probe could only enter the lacrimal sac from the common canaliculus after the sac was incised.

Conventional ultrasonography of three cases of mucopeptide concretions revealed a moderate-hyperechoic solid mass in the lacrimal sac. All three cases (3/3, 100%) had an oval-like shape with clear but not smooth edges and uneven internal echoes.

Two cases (2/3, 66.7%) had echo attenuation. Two cases (2/3, 66.7%) of large concretions were attached to the wall of the lacrimal sac (Figure 3A), while one case (1/3, 33.3%) of a small concretion had no contact with the lacrimal sac wall. CDU showed no blood flow signal in all these three cases (3/3, 100%; Figure 3B). The CT-DCG of the three patients showed irregularly shaped filling defects with dense, soft tissue at the defect. Two cases with large concretions (2/3, 66.7%) were connected to the lacrimal sac wall, while one case with a small concretion (1/3, 33.3%) was not connected to the lacrimal sac wall (Figure 3C). All three cases had mucopeptide concretions completely removed during the operation (Figure 3D).

Conventional ultrasonography of inflammatory granuloma revealed a moderate-hyperechoic solid mass in the lacrimal sac with clear, non-smooth edges, an irregular shape, and uneven internal echogenicity, all connected to the sac wall. CDU showed abundant blood flow signals (Figure 4A). The CT scan showed soft tissue mass in the lacrimal sac and nasolacrimal duct without any evidence of bone destruction (Figure 4B). This led to the pre-operative diagnosis of a lacrimal sac tumor, which was subsequently resected during the surgery.

One case of inflammatory granuloma with concretion showed a solid mass with medium-high signal echoes, unclear edges, irregular shape, and uneven internal echogenicity, with the base connected to the lacrimal sac (Figure 5A). CDU showed speckled blood flow near the sac wall (Figure 5B). The CT-DCG revealed an extensive irregular soft-tissue filling defect with an uneven margin attached to the lacrimal sac wall (Figure 5C), as well as a filling defect of soft tissue not adjacent to the sac wall (Figure 5D). Granulomatous hyperplasia was observed on the wall of the lacrimal sac during the surgery (Figure 5E).

Two cases of lacrimal sac tumors were identified with a moderate solid mass on traditional ultrasonography, filling the entire lacrimal sac in both cases (100%). The boundary of melanocytic carcinoma was clear, while that of squamous cell carcinoma was unclear, with non-uniform echoes (Figure 6A, 6B). The base of melanocytic carcinoma was widely attached to the sac wall, whereas in squamous cell carcinoma, the base was obscured due to the filling of the entire sac. CDU showed scattered punctate blood flow signals in melanocytic carcinoma and more abundant signals in squamous cell carcinoma (Figure 6C, 6D). CT results indicated soft tissue occupying the lacrimal sac and peri-lacrimal areas, with no evidence of bone destruction (Figure 6F). Both patients underwent resection of the lacrimal sac and nasolacrimal duct.

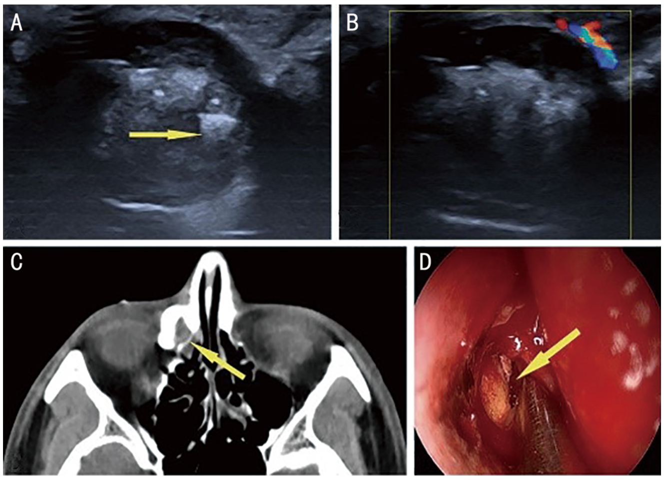

Figure 3 Imaging features of mucopeptide concretions in CDU and CT-DCG A: An oval-shaped mass with a clear, not-smooth edge and uneven internal echoes was detected on conventional ultrasound, with echo attenuation indicated by the yellow arrow; B: CDU showed no blood flow signal within the mass; C: Soft tissue mass in the lacrimal sac was observed without obvious bone destruction (yellow arrow); D: A large mucopeptide concretion was found during surgery (yellow arrow). CDU: Color Doppler ultrasound; CT-DCG: Computed tomography dacryocystography.

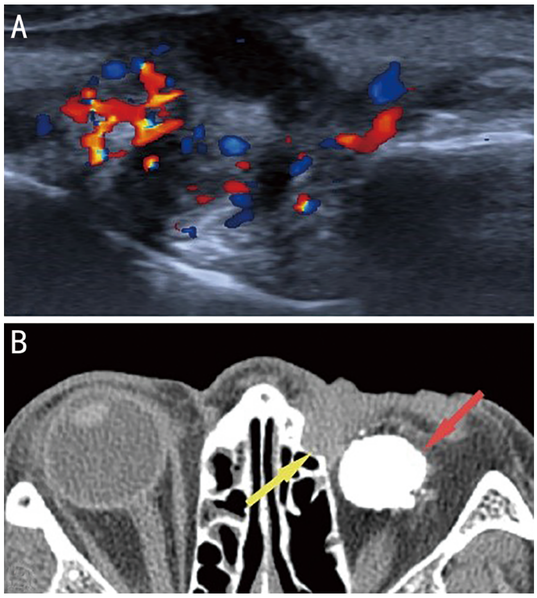

Figure 4 Imaging features of inflammatory granuloma in CDU and CT A: An irregularly shaped mass was observed with a clear, not-smooth edge and uneven internal echoes, with the base adhering to the sac wall was observed. CDU showed abundant blood flow signals. B: CT revealed a soft tissue mass in the lacrimal sac without obvious bone destruction (yellow arrow), and the high-density zone was identified as a hydroxyapatite orbital implant (red arrow). CDU: Color Doppler ultrasound; CT: Computed tomography.

DISCUSSION

Lacrimal sac tumors are uncommon, but more than 55%–100% are malignant, locally aggressive with a high recurrence rate, and potentially life-threatening[4-7,18]. Although lacrimal sac tumors can have serious consequences, the clinical diagnosis of lacrimal sac tumors remains unsatisfactory. A study found reported that 43% of lacrimal sac tumors were discovered inadvertently during DCR[19]. Some case studies have recently

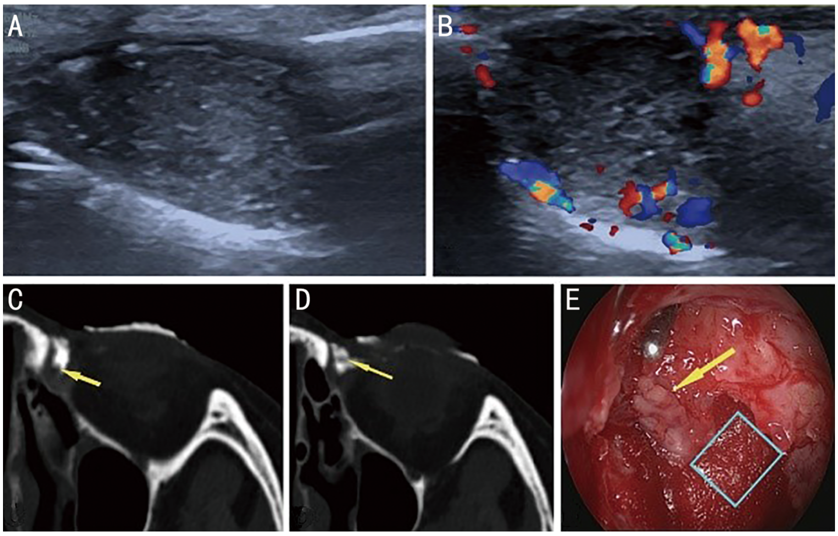

Figure 5 Imaging features of inflammatory granuloma complicated with concretion in CDU and CT-DCG A: An irregular shape mass with an unclear edge and uneven internal echoes inside, with the bottom adhering to the lacrimal sac; B: CDU showed speckled blood flow near the sac wall; C: CT-DCG showed extensive irregular soft-tissue filling defect with an uneven margin attached to the lacrimal sac wall (yellow arrow); D: CT-DCG showed a filling defect of soft tissue not adjacent to the lacrimal sac wall (yellow arrow); E: Granulomatous hyperplasia can be observed on the wall of the lacrimal sac during surgery (yellow arrow). The blue rectangular area represents the intraoperatively resected mucosa for pathological examination. CDU: Color Doppler ultrasound; CT-DCG: Computed tomography dacryocystography; CT: Computed tomography.

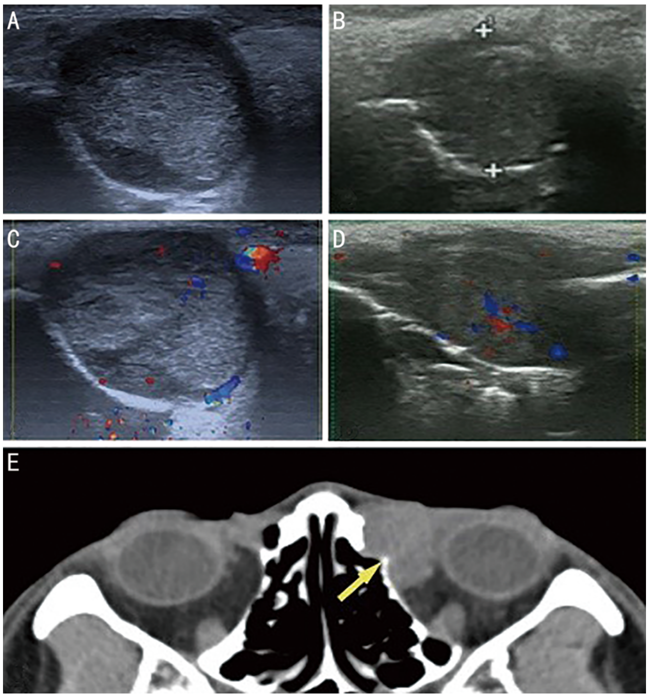

Figure 6 Imaging features of lacrimal sac tumor in CDU and CT-DCG A: A moderate echogenic solid mass filled the entire lacrimal sac, with a well-defined border and inhomogeneous internal echoes; B: A moderate echogenic solid mass filled the entire lacrimal sac, with an unclear border and inhomogeneous internal echoes; C: CDU showed scattered punctate blood flow signals in melanocytic carcinomas; D: CDU showed more abundant blood flow signals in squamous cell carcinomas; E: CT showed soft tissue mass in the lacrimal sac with slight bone erosion (yellow arrow). CDU: Color Doppler ultrasound; CT-DCG: Computed tomography dacryocystography; CT: Computed tomography.

reported that lacrimal sac tumors were discovered inadvertently during surgery[8-10]. This delayed diagnosis may be due to two reasons. First, the signs and symptoms of sac tumors are often similar to dacryocystitis, and in some cases, a definite tumor mass may not be palpable at early stages. Additionally, preoperative examinations remain insufficient due to the low incidence of these tumors. A web-based questionnaire study from the Surgeons of the American Society of Ophthalmic Plastic and Reconstruction reported that less than 5% of patients underwent orbital CT before lacrimal surgery[11].

In this study, we provided the first detailed description of the imaging changes of CDU in lacrimal sac SOLs. In the 21 cases included in this study, CDU detected SOLs, including a tiny lacrimal sac polyp with a diameter of approximately 1×2 mm^2, which was not diagnosed by CT angiography. The SOLs' edges, shapes, internal echo, position, and blood flow signals could be visualized in the CDU. Polyps, mucoceles, and mucopeptide concretions exhibited characteristic changes on CDU examination. Thus, CDU plays an important role in the differential diagnosis of diseases. Notably, large mucopeptide concretions and mucoceles can appear as soft tissue density masses on CT-DCG or CT, similar to the tumor's appearance. Moreover, these masses can be palpable in the lacrimal sac area, requiring full differentiation from lacrimal sac tumors. Therefore, additional tests such as contrast-enhanced CT, magnetic resonance, or contrast-enhanced magnetic resonance may be necessary to differentiate them. Our observation has shown that CDU can help differentiate large mucopeptide concretions and mucoceles from lacrimal sac tumors. However, no characteristic changes were observed in the morphology of the tumor, inflammation, and inflammatory granulomatous stones.

CT is widely used in the clinical examination of lacrimal sac soft-tissue orbital lesions, demonstrating a lacrimal sac mass and the extent of bone erosion and/or invasion into surrounding structures. Additionally, a CT-DCG of the lacrimal drainage system can identify the location of the lacrimal sac and provide additional anatomical information, such as an angiographic defect that can be caused by the lacrimal sac SOL. Several studies have suggested that preoperative DCG, CT, or a combined CT-DCG are essential for those patients being considered for an endoscopic DCR[20-23]. In the present study, except for a small polyp, both CT-DCG and CT could not present characteristic imaging changes in all the soft tissue SOLs. In our study, CDU could not identify a case of inflammatory granuloma combined with concretion, while the CT-DCG indicated that the two filling defects might be independent. Although CT and CT-DCG have many advantages in detecting lacrimal sac SOLs, their resolution is relatively low. Therefore, they cannot demonstrate whether the SOLs contain blood supply, leading to shortcomings in the differential diagnosis of the disease. Additionally, the current preoperative CT or CT-DCG examination rate is still low, resulting in frequent misdiagnoses of lacrimal sac tumors[8-10,19]. We believe this may be due to the low prevalence of lacrimal sac tumors, the cost of CT examination, radiation, and the examination duration.

Compared with CT, CDU cannot penetrate the bone, thus giving CT a better advantage for detecting bone or surrounding structure involvement in SOL. However, CDU has a higher resolution for soft tissues, allowing it to detect blood flow to SOLs. Furthermore, CDU inspection is more convenient, less expensive, and radiation-free. As the current rate of preoperative CT or CT-DCG examinations before DCR is low, we suggest that CDU can be used as a routine examination before DCR in patients who have not had preoperative CT or CT-DCG. Additionally, CT or CT-DCG can be supplemented to provide more evidence for planning treatment strategies for any detected SOLs.

In summary, CDU can detect the morphology and internal blood flow signals of lacrimal sac SOLs, making it an important diagnostic method for discovering and observing them. Additionally, CT or CT-DCG are important conventional examination methods for diagnosing lacrimal sac SOLs and have the advantage of observing structural damage around the lacrimal sac mass. However, the current preoperative CT or CT-DCG examination rate is still low. We suggest that CDU can be used as a routine examination to exclude lacrimal sac SOLs before DCR when preoperative CT or CT-DCG is absent.

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