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THE USE OF ULTRASOUND IN THORATIC SURGERY

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Abstract

This communication discusses the possibilities of the use of ultrasound examinations in thoracic surgery. It describes the most frequent indications and methods of ultrasound examinations. It also mentions other options of using ultrasound in situations not introduced in current surgical practice yet. The benefits of this examination and also the knowledge resulting from our own clinical research are discussed.

Key words

Ultrasound, Thoracic surgery, Lung, Mediastinum

Abbreviations used

3D, three-dimensional, 4D, four-dimensional imaging; EBUS, endobronchial ultrasound examination; ECHO, echocardiography; FNA, fine-needle aspiration biopsy; NSCLC, non-small-cell lung cancer; RG, radiography; US, ultrasound; VATS, video-assisted thoracic surgery; VMS, video-assisted mediastinoscopy

INTRODUCTION

Ultrasonography examination presents an easily available, modern and constantly developing imaging method. The first ultrasound units were designed for medical purposes half a century ago. Some instruments were based on the principle commonly used in industrial defectoscopy; others were based on the Doppler principle. The instruments created one-dimensional A-mode imaging. In the first half of the seventies, instruments working on both principles were used. Currently, instruments with two-dimensional imaging, the dynamic B-mode instruments, are mostly used, usually with the option of Doppler imaging technology. Ever new instruments are being designed in the process of continuous development. Instruments presenting tissue imaging in colours and in motion are available, as well as instruments using colour duplex methods for the examination of vascular structures. Echo-contrast agents for intravenous administration have been developed and used. Instruments presenting 3D or 4D representation, i.e. spatial and stereoscopic imagings, are available (*1*). An ultrasound unit doesn't present serious expensiveness today.

Ultrasound examinations have become the gold standard in the diagnostics of a number of diseases. Benefits of the examination speed and accuracy are enormous; a great advantage is also the possibility of examining patients with mobile ultrasound units, first and foremost in rapid examinations in emergency departments, as well as in patients difficult to transport, in patients requiring artificial ventilation or connected to elimination instruments, etc. Its merits also include the even today verified harmlessness and thus also the repeatability of these examinations. Its advantage that cannot be neglected is the good tolerance of the examination by the patients. Ultrasound examinations are currently used in all fields of surgery, not any differently in thoracic surgery.

Current status of ultrasound diagnosis of thoracic pathology

Ultrasound examinations in connection with thoracic surgery are indicated on a great many grounds.

First of all, these are the following conditions:

Diagnostics of pleural exudates

The diagnostics of pleural exudates is the most common indication for the use of ultrasound in thoracic surgery. One of the merits of the examination is the option of both qualitative and quantitative assessment of the nature of the exudate. A great advantage is the determination of the nature of the exudate (exudate, haemothorax, pyothorax). Another appreciable advantage is the option of repeated examinations with the assessment of the dynamics of the thoracic exudate development as regards both its quantity and character. With ultrasound, one can also judge the effectiveness of thoracic drainage. An experienced ultrasonographer can evaluate and diagnose the presence of pneumothorax. Radiography continues being the standard thoracic imaging method, but it is not sufficient in case of pleural exudate; it cannot provide high-quality determination of the quantity and exact site of the exudate. Pleural exudates can be detected with routine X-ray examination only if the quantity of the liquid exceeds 200–300 ml (except for encapsulated exudates in interlobar fissures). If atelectasis of one whole lung develops, radiography usually cannot differentiate it from an extensive pleural exudate.

Treatment of pleural exudates under ultrasound imaging guidance

Ultrasound assistance in puncture evacuations of pleural exudates (*Fig. 1*) is a great asset in the prevention of possible complications accompanying this intervention. First and foremost, these include injuries to the lung or vascular structures and, if a high position of the diaphragm is present, also injuries to the liver or spleen. Ultrasound monitoring also eliminates the possible failure to catch the liquid isolated in pleural septa. The US determination of the most suitable point for the execution of the planned puncture is also of great advantage.

Fig. 1
US assistance by needle evacuation of pleural exudates. 1 – effusion, 2 – Veress needle, 3 – sediment, 4 – lung parenchyma.

Fig. 2
The intraoperative image of the endosonography linea probe. The examination of the lung, coin lesion

Treatment of empyemas – drainage, open drainage, empyemectomy

Targeted drainage, or open drainage, is the most frequent surgical therapy of empyema. It is often connected with rib resection. Correct localisation of the empyema is a precondition for successful surgical therapy. It is convenient if the extent of the

empyema is marked directly on the skin with a disinfecting solution or indelible marker pen. Peroperative US assistance is also advantageous: we use it mainly for the determination of the boundary of the empyema cavity in mature empyemas with sufficiently thick layer. It is also used in empyemas that are indicated for complete excision in toto without opening the capsule – empyemectomy.

Ultrasound lung examination

Routine ultrasound examinations of the lung parenchyma are not possible because of the hyperechogenic barrier formed by the air in the examined lung. Only peripheral air-free areas of the peripheral lung parenchyma, closely adjacent to the chest wall, are available to current examinations. These are primarily peripheral lung tumours, both of inflammatory or malignant aetiology, or areas of air-free lung tissues developing on the basis of lung embolisation or another reason. More centrally located lung structures cannot be examined with ultrasound. Or, as the case may be, they can be examined after lung collapse (see below) or with the EBUS method.

Peroperative ultrasound lung examination

Airless collapsed lungs or even the lung parenchyma can be thoroughly examined with ultrasound. The examination proceeds peroperatively in cooperation of the surgeon with the sonographer. The examination is not quite common and it has been still used only very rarely in the Czech Republic. The probe must be applied on the lung surface (*Fig. 2*); even small amounts of air in the lung examined or some air gap between the lung and the probe would make this examination impossible. We indicate this examination primarily in VATS on the grounds of precise identification of small lung lesions (*8,9*). That is to say, small lung lesions may not always be visible or accessible by palpation, by digital examination or by examination with endoscopic instruments. The pathological difference in tissue consistence may not be well detectable with an endoscopic instrument (a lung focus is usually of thicker consistency than the surrounding lung parenchyma). Small lung lesions usually present primarily tumours, both benign and malignant, both primary and secondary tumours (*Fig. 3*). Even small inflammatory foci cannot be excluded. In the localisation of lung pathologies, we can determine the subsequent procedure, i.e. extirpation using endoscopic surgical technique or open surgery if necessary. Thanks to the accurate localisation, we can choose a short-targeted thoracotomy in the correct intercostal space and on the right site. Other methods of identification of a small lung focus before surgery, i.e. the introduction of a metal guide wire under CT control or staining of the focus under CT control, can fail. A fine wire usually dislocates after the lung collapses; percutaneous introduction of a fixed embolisation coil into the focus is more promising (*10*). The stain, which is usually patent blue dye, can flow out into a large area. The stain as well as a metal guide wire do not necessarily intercept the focus being sought. Ultrasonography is not conductive in

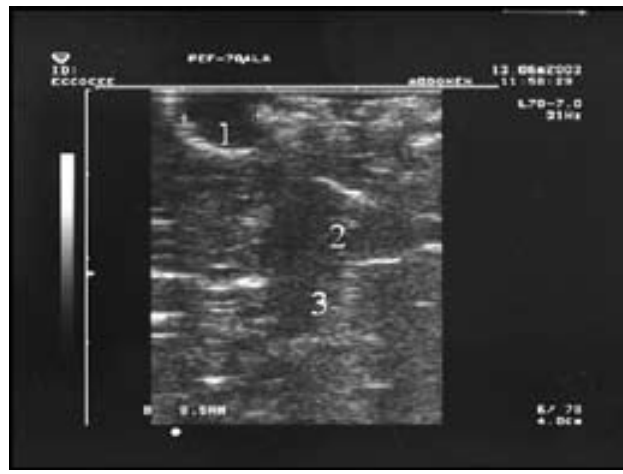

Fig. 3
The echographic image of the collaped lung. 1 – lung module (metastasis)
2 – vessel 3 – small bronchus

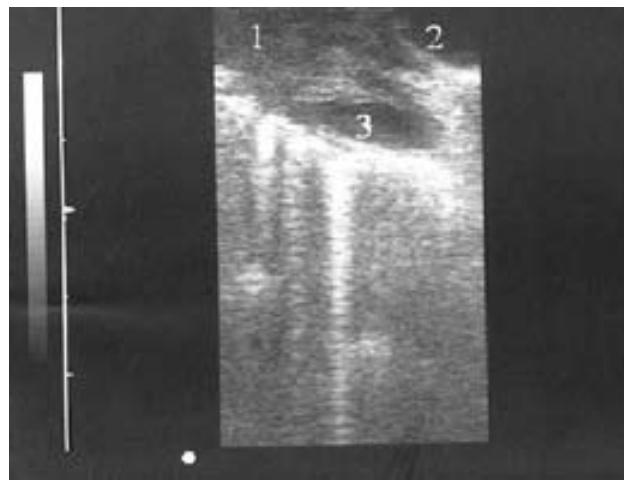

Fig. 4
Echographic image of the mediastinal tissue
1 – tumor, 2 – vein azygos, 3 – vein cava superior

the diagnostics of interstitial pulmonary processes. It can, however, assist in the decision-making and assessment of the invasiveness of lung tumours into their vicinity (into the thoracic wall, pericardium, vessels, diaphragm, oesophagus...). This examination is usually indicated during open surgery through thoracotomy or sternotomy.

EBUS – ENDOBRONCHIAL ULTRASONOGRAPHY

It is a well-established endosonographic examination method. An ultra-thin ultrasound probe is introduced into the bronchial tree. In this way, pathologies of the lung parenchyma (*2*) in the available vicinity to the bronchial tree as well as affections of the bronchial tree can be diagnosed. Also, formations in the mediastinum can be examined (*3,4*) or very important examinations of the lymph nodes (*5,6,7*) can be performed. This intervention can be connected with FNA – ultrasound guided fine-needle aspiration biopsy.

Ultrasound examination of pleural lesions

Both inflammatory and benign or malignant metastatic tumorous pleural affections of larger extent, i.e. not tiny nodular affections, are easy to diagnose with ultrasonography. Even ultrasound-guided pleural biopsies are possible.

Ultrasound examinations of thoracic wall tumours

The determination of a resection line with a sufficient and safe margin, recommended in primary tumours of the thoracic wall at a distance of 4 cm from the tumour boundary, is absolutely crucial for oncological radicality and any sense of the operation. Because of the impossibility of any macroscopic judgement of the extent of tumour invasion into the thoracic wall when the skin incision is made, the US examination is irreplaceable. Faulty determination of the resection boundary is a fatal error. Ultrasound can help us determine the resection boundary peroperatively on the basis of the invasion into the muscles, diaphragm, lung, and pericardium. Correct boundary of the resection must always be checked by intraoperative histological examination.

Ultrasound examination of lymph nodes

In the staging (*11*) of not only lung carcinoma but also of other malignant diseases of the organs of the thoracic cavity, thoracic wall, and mamma, the examination of the lymph nodes is of crucial importance. The examination can only diagnose enlarged lymph nodes: these can be enlarged due to a tumorous affection, but also owing to inflammatory processes. A US examination can recognise the probable aetiology (*12*) of the lymphadenopathy: While a lymph node enlarged due to inflammation has a homogeneous structure with hilus-type vascularisation, a lymph node infiltrated by a tumour is always inhomogeneous with areas of different echogenicity, the vascularisation being usually of peripheral type with slow blood flow, characteristic of tumorous neovascularisation. Enlarged lymph nodes often have bizarre shapes, they can form packets. A triangular from is typical of a physiological lymph node; this changes into a spherical form in malignantly infiltrated lymph nodes. US examination can therefore determine suspect nodes for histological analysis.

Fig. 5
The multifrequency endosonography linear laparoscopic probe. The flexible variety of the probe (two directions, ± 90 degrees both longitudinal and transversal) facilitate better manipulation.

Ultrasound examination in mediastinoscopy

This is not a standard examination method (*Fig. 4*). However, within the framework of investigation into the use of ultrasound examinations, we have obtained remarkable findings even in this surgical invasive examination method. In the examinations, we rely, as a rule, on visual perception supplemented with the knowledge of CT findings, then on digital examination of the given area as well as on the knowledge of the anatomical situation of the given locality. The presence of large vascular structures presents the most severe possible complication of this invasive examination, namely heavy bleeding due to injury to large vessel bundles. With the internal ultrasound examination, we can exactly determine the course of large vessels. Furthermore, we can also examine pretracheal lymph nodes, which are mostly out of reach for the mediastinoscope. We have the option of exactly selecting suitable lymph nodes or other pathological infiltration of the mediastinum for safe biopsy. The possibility of differentiating fibrous capsules of tumorous infiltrations from the tumorous matter and thus eliminating faulty biopsy presents a remarkable advantage.

RESULTS

At our surgery department there works an experienced colleague sonographer. Her valuable virtue is her ability to consider and examine the given patient's condition from a surgeon's point of view, to identify herself with the problems of subsequent possible surgical treatment.

Treatment of pleural exudates and empyemas

At our First Department of Surgery of St. Anne's Faculty Hospital, we have very good professional experience with US-guided treatment of pleural exudates and empyemas. For the treatment of thin exudates we have been using a Veress needle, a needle with covered point. Since the introduction of this method, we have not recorded any injury to the lung or pneumothorax development. If the pleural cavity must be drained, we use thoracic drains Ch 28 and larger. We always drain with open preparation in order to prevent lung or intrathoracic structure injuries. In the treatment of empyema, its accurate localisation determined by means of ultrasound is of crucial importance. It is of advantage if the empyema boundaries can be drawn on the skin before the operation, namely in the exact position of operation, i.e. on the contralateral side with the upper limb on the affected side elevated.

Intraoperative lung examination

We perform peroperative lung examinations and US examinations during the VMS within our research plan. It produces a lot of useful knowledge. In total, we have peroperatively examined the lung tissue during VATS or thoracotomy of 27 patients. In five or four of them, the examination was not successful; these were examinations during VATS. In two cases, the focus was too distant from the probe or from the visceral pleura, i.e. over 45 mm. In contrast to literary data, we were able to detect foci even at a distance of 40–45 mm from the ultrasound probe, while accessibility of only max. 35 mm is usually reported. In one case, the focus was out of reach owing to too stiff, anatomically unfavourably positioned adhesions in the pleural cavity. In one case, sufficient pulmonary desufflation could not be attained. In these described cases in reality the US method did not fail. In the last "unsuccessful" case, we failed to localise a small lung focus diagnosed with CT, but it could not be detected even by palpation during the subsequent surgical revision. On the subsequent control CT examination, this focus could not be diagnosed, either. In this case, the failed US examination was actually correct. In other cases, the foci were successfully localised. Detection was targeted on macroscopically suspect (changed colour, elevation above the surrounding pleura) and deeply localised foci that could not be diagnosed macroscopically or by palpation. The minimal size of the identified lesion was 3 mm. It was possible to remove these foci by means of VATS, or, in six cases, the ideal site for a short thoracotomy necessary for the elimination of the focus could be chosen owing to the focus size or its location in the fissure or its too central position. The VATS treatment of pulmonary lesions with non-malignant aetiology, or of a solitary lung metastasis is of advantage, particularly in patients with higher risk due to their internal diseases. We were able to save these patients from thoracotomy, which itself is an injury. Data in the literature state that a thoracotomy itself represents an injury equivalent to a functional loss of pulmonary tissue in the extent of lobectomy. No doubt, a great asset is also represented by the reduction of postoperative pain. Smaller quantities of analgesics can be applied postoperatively;

easier expectoration can be attained as well as better ventilation and rehabilitation. Specification of the pathology diagnosis is typified in Table 1. If primary pulmonary malignancy was proven peroperatively, we chose subsequent anatomical pulmonary resection with the exception of one very risky patient. The first results of ultrasound use in mediastinoscopy are interesting. It seems that a more accurate selection of the suitable site for excision by means of ultrasound, or of the suitable focus intended for biopsy, presents a promise for the future as it enables a reduction in the number of non-representative samples. From seven mediastinoscopies carried out and combined with US examination, informative biopsy was obtained six times; in one case, the negative finding was confirmed. In VATS and VMS, we use an ultrasound probe intended and designed for laparoscopic interventions (*Fig. 5*). We are in the first stage of our efforts to achieve ultrasound-guided specification of selected mediastinal lymph nodes within the framework of our investigation into the sampling of mediastinal lymph nodes in primary pulmonary carcinoma. Our department advocates systematic mediastinal lymphadenectomy. The first information from the examination of the mediastinum is encouraging, both for departments that reject the method of mediastinal lymphadenectomy and are advocates of sampling only, and also for departments, including our own, that prefer the surgery of lung metastases. General position concerning the possibility of lung metastases spreading into regional mediastinal lymph nodes is not clear yet.

CONCLUSION

The ultrasound examination has found its useful role even in thoracic surgery. However, it appears that the possibilities of ultrasound application in the field of thoracic surgery have not been exhausted yet.

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VYUŽITÍ ULTRAZVUKU V HRUDNÍ CHIRURGII

S o u h r n

Ultrazvukové vyšetření je snadno dostupnou, dále se rozvíjející zobrazovací metodou. Své uplatnění si nachází i v oblasti hrudní chirurgie. Nejčastější indikací ultrazvukového vyšetření tohoto oboru je diagnostika pohrudničních výpotků a asistence při jejich punkční evakuaci či drenáži. Velmi cenné je ultrazvukové vyšetření v rámci rychlé diagnostiky pacientů ošetřovaných po úraze. Přínosné je vyšetření endobronchiální, které může být spojeno s ultrazvukem naváděnou tenkojehlovou biopsií. Vyšetřena může být jak patologie bronchiálního stromu, tak i plicního parenchymu, mediastina či lymfatických uzlin. Velmi přínosná je peroperační ultrazvuková lokalizace drobných plicních lézí ošetřovaných videotorakoskopickou technikou. Ve stadiu prvních poznatků je stanovení přínosu ultrazvukového vyšetření v diagnostice patologie lymfatických uzlin mediastina. Vyšetření je prováděno jak při torakotomii, tak i při mediastinoskopii.

REFERENCES

1. *Hrazdira I.* Concise repetitorium of ultrasonographyAudioscan 2003; 5–15.
2. *Murasugi M, Onuki T.* The role of video-assisted thoracoscopic surgery in the diagnosis of the small peripheral pulmonary nodule. Surg Endosc 2001; 15: 734–736.
3. *Catalano MF.* Endoscopic ultrasound-guided fine needle aspiration in the diagnosis of mediastinal masses of unknown origin. Am J Gastroenterol 2002; 97: 2559-2565.
4. *Devereaux BM.* Clinical utility of EUS-guided fine-needle aspiration of mediastinal masses in the absence of known pulmonary malignancy. Gastrointest Endosc 2002; 56: 397–401.
5. *Wallace MB, Kennedy T, Durkalski V, et al.* Randomized controlled trial of EUS-guided fine-needle aspiration techniques for detection of malignant lymphadenopathy. Gastrointest Endosc 2001; 54: 441–447.
6. *Wiersema MJ.* Evaluation of mediastinal lymphadenopathy with endoscopic US-guided fine needle aspiration biopsy. Radiology 2001; 219: 252–257.
7. *Rosenberg JM.* Endoscopic ultra-sound/fine-needle aspiration diagnosis of a malignant subcarinal lymph node in patient with lung cancer and a negative positron emission tomography scan. Chest 2002; 122: 1091–1093.
8. *Mattioli S, D'Ovidio F.* Transthoracic endosonography for the intraoperative localization of lung nodules. Ann Thorac Surg 2005; 79: 443–449.
9. *Piolanti M, Copola F.* Ultrasonicographic localisation of occult pulmonary nodules during video-assisted thoracic surgery. Eur Radiol 2003; 13: 2358–2364.
10. *Lizza N, Eucher P.* Thoracoscopic resection of pulmonary nodules after computed tomography – guided coil labeling. Ann Thoracic Surg 2001; 71: 986–989.
11. *Wallance MB.* Endoscopic ultrasound-guided fine-needle aspiration for staging patient with carcinoma of the lung. Ann Thorac Surg 2001; 72: 1861–1867.
12. *Hrazdira I.* Concise repetitorium of ultrasonography. Audioscan 2003; 48.