Pneumothorax resulting from subclavian puncture: a complication of permanent pacemaker lead implantation

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Pneumothorax is a mild complication during pacemaker lead implantation using the subclavian puncture technique. We report on five-year experience in 433 pacemaker lead implantation procedures in 379 patients. The cephalic vein route was solely used in twelve patients. Three procedures were performed over time in four patients and one patient needed four repetitive punctures for pacemaker lead implantation and replacement. Thus 421 punctures were carried out in 367 patients. Eleven cases of pneumothorax were observed: in eight patients (1.9%) a partial pneumothorax occurred and in three patients (0.7%) the pneumothorax was nearly complete. In the latter patients a chest tube was inserted and hospital admission was prolonged for 3, 6 and 6 days, respectively. Old age with a corresponding abnormality in the form of chest deformation were predominantly found in the patients with this type of complication. (*Neth Heart J* 2004;12:101-5.)

Key words: lead implantation, morbidity, pneumothorax, subclavian puncture

The incidence of pneumothorax after subclavian punctures varies in the literature on pacemaker implantation. It is assumed to be low, in the range of 0.7 to 1%, but higher incidences have also been reported, up to 5.2%.[1-12] This incidence is on the one hand dependent on the exact definition of pneumothorax itself and clinical recognition, and on the other hand on the exact recording of complications of pacemaker or ICD lead implantation. Pneumothorax is literally defined as the presence of air in the pleural cavity, with secondary lung collapse.[13] Spontaneous pneumothorax may occur in two different patient groups: primary spontaneous pneumothorax, which occurs dominantly in young persons without underlying lung disease and secondary spontaneous pneumothorax, which is usually caused by rupture of a subpleural bleb in patients with lung disease. Pneumothorax secondary to subclavian puncture forms a third group of patients. Independent from the pathophysiology the treatment methods range from simple aspiration, chest tube drainage, chemical sclerosis of the pleura, to thoracoscopy or even thoracotomy. In this report we have reviewed all cases of pacemaker lead implantations or procedures where a new lead had to be (re)introduced into the vein and where the subclavian vein was punctured. Treatment and subsequent events are reported.

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Methods

Between 1994 and 2001, 433 lead implantation procedures were performed in 379 patients. There were 197 male and 182 female patients and the average age was 74.5±11.5 years, ranging from 15 to 97 years. In 12 out of these 433 procedures, the cut-down technique of the cephalic vein was solely applied, leaving 421 procedures with subclavian vein puncture. In nine patients the cephalic vein route as well as the route of subclavian puncture technique was used. In six patients subclavian puncture was attempted on both sides, the right as well the left side.

Subclavian puncture using the modified Seldinger technique was performed with the patient in a fully supine position. The vein is usually approached blindly. The left or right vein is entered at the junction of the middle and inner thirds. Placing the patients in the reverse Trendelenburg position may facilitate venous access, but this cannot be used in the catheterisation laboratory. When necessary, the axillary and subclavian

vein can be visualised by intravenous contrast injection in the peripheral arm vein. In a patient with chest wall abnormalities or deformation of the clavicle the usual landmarks may be altered, especially in patients with a history of an old clavicle fracture. After the vein has been engaged with the puncturing needle, the guide wire, introducer and valved venous sheathes are inserted successively.

In all patients a chest radiograph in standing position and in two directions (anteroposterior and lateral) was carried out the day following the pacemaker lead implantation. All chest radiographs were reviewed for the presence or absence of pneumothorax, and in case of doubt the radiographs were re-reviewed by a radiologist (JdP). A small pneumothorax was defined as less then 10% reduction of lung tissue. Haematothorax was diagnosed when pneumothorax was observed in combination with a fluid level in the thorax. All records were reviewed retrospectively for treatment, subsequent events due to the pneumothorax and additional hospital admission days.

Results

In total, 421 procedures were performed to implant a pacemaker lead or to reposition a lead with new attempts to access the venous system. In some patients double puncture of the subclavian vein was used to implant a DDD pacemaker, where puncturing the subclavian vein twice was favoured instead of using a single puncture site to insert two leads (single puncture-double wire technique).[11] This kind of procedure was considered to be a single procedure. In six patients an attempt was made to puncture the right as well as the left subclavian vein, because cannulation of the vein was not successful at one side. The right-sided approach was more favoured and used in 314 patients compared with the left-sided approach in 113 patients. In eleven patients a pneumothorax was found: in 4 of the 113 (3.5%) patients in whom a left-sided approach was used and in 7 of 314 right-sided approaches (2.2%, p=ns).

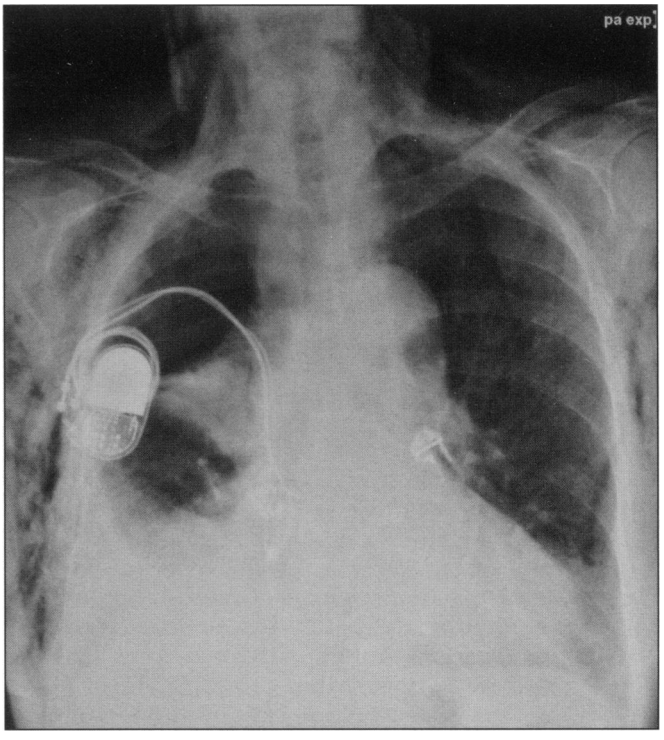

Figure 1. The anteroposterior view of the chest radiograph clearly shows a large right pneumothorax, which was treated with a chest tube. Subcutaneous emphysma was also noticed in four patients, with or without a pneumothorax.

In six patients it was a small apical pneumothorax (less then 10%) and in two cases a partial pneumothorax with a small amount of basal fluid levels, in one a haematothorax and in the other pleural effusion. In all these cases the recovery was spontaneous and complete. The minimum, median and maximum additional hospital admission days were none, three and seven days, respectively. The first of these patients was closely followed up in the outpatient department. The three

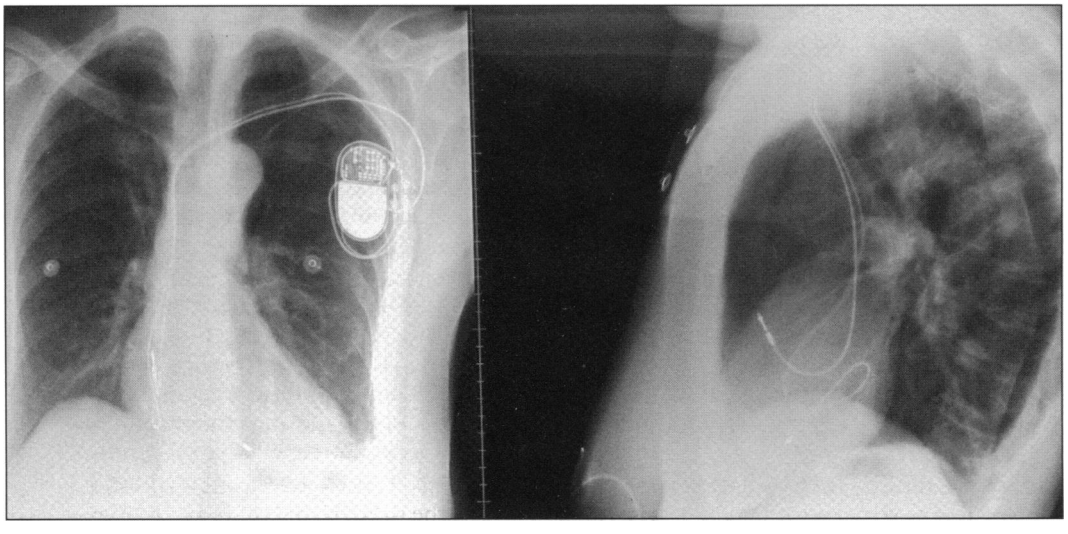

Figure 2. Chest deformation in older patient with iatrogenic pneumothorax. Note the low position of the median at the junction with the sternum.

other patients with a more extensive pneumothorax (figure 1) had no signs of tension pneumothorax. These patients were treated with a chest tube and their recovery was uneventful. The additional hospital admission days were two, six and six days, respectively. In four patients subcutaneous emphysma was also noticed (figure 2).

Two patients with a pneumothorax were special cases. One young boy had an upgrade of a VVI to a DDD pacing system. He had a long and complicated history of lead fracture and pacemaker infection. The subclavian vein was punctured under fluoroscopy and it was essential to avoid damage to the present ventricular lead at any price. In another rather young patient (male, aged 52 years) the clavicle was deformed because of an old fracture. The other nine patients were older compared with the group of patients without pneumothorax: 81.6±5.4 years of age vs. 74.5±11.1 years (p=0.004) and seven out of the eleven patients (ns) were female. Review of the chest X-ray in the patients with pneumothorax showed chest deformation in three out of nine (figure 2). The review of chest radiographs also disclosed some other anomalies, such as undetected lung cancer in one patient, undetected lung metastasis in a patient with diagnosed cancer, a hiatus hernia in a single patient and pulmonary congestion in eight patients.

Discussion

In a large survey of pacemaker implantations it was shown that the subclavian puncture technique and the use of the introducer method was favoured in 95% of lead placements.[14] Several other techniques have been described for gaining access to the venous system, of which the cut-down technique of the cephalic vein is the most important. The disadvantage of this method is the assumed extensive skin and muscle dissection needed for the visual approach of the vein. Many cardiologists consider this approach to be a privilege of the surgeon. In a randomised study, Calkins et al. report a successful implantation rate of 64%, where 100 patients were randomised to subclavian vein puncture after contrast injection in the cubital vein and the other 100 patients to venous cut-down of the cephalic vein.[15] Another report shows a failure rate of 17% when the cut-down technique of the cephalic vein is used alone.[16] Unsuccessful access to the subclavian vein was seen in a few patients in this series, but it has been reported in up to 8.3% of all attempts.[3]

Other techniques may be used for gaining access to the venous system, such as puncturing the axillary vein. The axillary vein forms a continuity with the subclavian vein outside the thorax and it runs parallel to the deltopectoral groove, which is a groove between the deltoid muscles and the pectoralis major muscle. The cephalic vein runs almost parallel to the axillary vein but the cephalic vein makes a rather sharp curve to drain into it in a perpendicular way. This sharp curve, however, may hamper passage of the lead into the

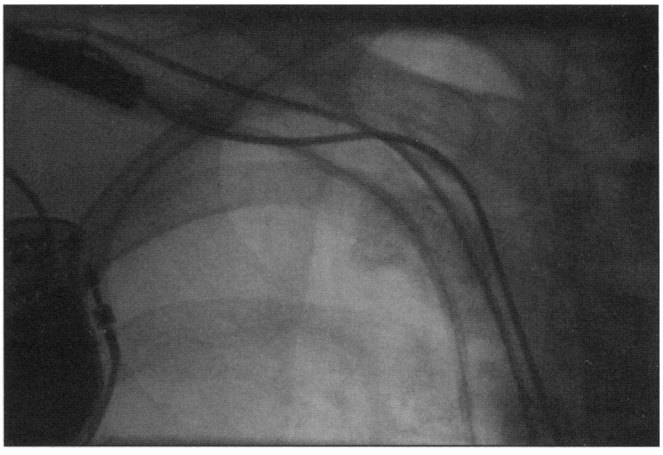

Figure 3. Close-up frame of fluoroscopy control with respect to a pneumothorax. The faint density superimposed on the clavicle and the first rib is better seen during fluoroscopy due to its movements during respiration.

veins, especially screw-in leads with a rather inflexible distal tip. The guiding wire of the puncture set can be introduced after blind puncture of the vein. It has to be stressed that the needle angle should be tangential to the ribs directing craniomedial.[17]

Another more or less alternative route is the technique of puncturing the subclavian vein, as proposed by Byrd. He proposed an extrathoracic approach, which involves cannulation of the subclavian vein as it passes over the body of the first rib prior to entering the thoracic inlet. The technique includes manoeuvring the introducer needle from the clavicle to the first rib by a series of partial withdrawals and reinsertions, visualised by fluoroscopy. The needle is advanced 'posteriorly' along the rib until the vein is punctured. Orientation is maintained by touching the rib with each manoeuvre. It is claimed that in all 213 cases cannulation was successful and without major complications.[18]

An almost abandoned technique is cannulation of the external jugular vein.[19] The lead has to be tunnelled over the clavicle, which may lead to skin erosion and infection. This latter problem is considered a major complication. The jugular vein is not suitable for the implantation of ICD leads either. Leads can be tunnelled under the clavicle, but this procedure may endanger the axillary vessels and brachial plexus and needs extensive and skilled surgery. It may be used in small children.[20]

The disadvantages of puncturing the subclavian vein are numerous (see table 1), but may counter weigh the advantages: 1. access to the subclavian vein is relatively easy and swift; 2. less surgery and anaesthetic is required; 3. the vein may be used repeatedly, especially in case of upgrades of the VVI or AAI to a DDD pacing system or replacement of failing pacemaker leads and more then one lead (up to three leads, including an ICD lead) may pass through the subclavian vein. Use of the subclavian vein should be con-

Table 1. Side effects or complications of subclavian vein puncture in patients with permanent pacemaker or ICD lead implantation.

Complications	Author(s)	Reference
Pneumothorax	Several	1-12
Haematothorax	Aggarwal, Shahian	8-25
Lead insulation damage	Arakawa	26
Lead fracture	Magney	9
'Subclavian crush' syndrome	Belott	14
Death by unrecognised puncture of the left pulmonary artery	Kessinger	27
Thoracic duct injury	Parsonnet	11
Arteriovenous fistula	Parsonnet	11
Chylocoele (possibly related to puncture)	Hall	28
Transient injury of brachial plexus in 4.3%	Fiorista	6
Infraclavicular brachial plexus block	Stone	29
Periosteal process around lead	Szili-Torok	30

sidered whenever the cephalic vein cannot be located readily or is too small to permit passage of an endocardial lead. Furthermore the risk of pneumothorax can be minimised by knowledge of the patient's anatomy and attention to details, as was evident in the patient with the old fracture of the clavicle. In our series, pneumothorax occurred in patients with a complicated procedure (upgrade in the young patient) or in very old patients with deformation of the chest. The risk of more lateral or medial puncture is unclear. Some authors claim that the more lateral puncture of the subclavian vein has a greater potential for damage to the apex of the pleural space.[21]

Low incidence of reported pneumothorax as a complication of permanent pacemaker lead implantation may be caused by the poor recognition of this type of complication. Several events may indicate that a pneumothorax has occurred, such as: 1. air aspiration during attempts to puncture the subclavian vein; 2. sudden chest pain; 3. respiratory distress; 4. sudden hypotension. Any of these events should be followed by prompt fluoroscopy of the upper lung fields and critical evaluation of the patient. Monitoring of the saturation at the fingertip is very helpful in the management of the patient. Pacemaker implantation should be stopped in case of respiratory distress (saturation below 90%) and/or hypotension.

In the literature a wide range of pneumothoraces have been reported as complications of pacemaker or ICD lead implantation, or attempts to gain access to the venous system by puncturing the subclavian vein: the incidence varies between 0.7% to 5% (table 2). The definition of pneumothorax is clear, but the detection by routine chest X-ray is not fully reliable. In some

Table 2. Pneumothorax as a complication of pacemaker and/or ICD lead implantation.

Author	Year	No of patients	Incidence	Remarks
Bartecchi	1976	51	1.9	Emergency bedside procedures
Littleford	1979	164	2.4	14 attempts unsuccessful!
Miller et al.	1980	71	2.8	Also used in children
Zwirner et al.	1980	552	0.9	Five-year experience in a general hospital
Furman	1986	46	2.2	Subclavian vein used in only 16.4%.
Fiorista et al.	1986	101	3.0	Also transient injury of brachial plexus in 4.3%
Chauhan et al.	1994	2059	0.7	86% received a VVI pacemaker
Aggarwal et al.	1995	1059	1.8	Patients with first endocardial permanent pacemaker
Magney	1995	507	0.7	Retrospective and cadaver study
Kiviniemi et al.	1998	446	1.3	381 procedures with subclavian puncture
Parsonnet et al.	1999	406	5.2	29 implanting physicians over five years
Calkins et al.	2001	200	2.0	Pneumothorax at contralateral chest in one patient
Res et al.	2002	421	2.6	Five-year experience in a general hospital

reports underdetection with routine chest radiography may account for 30%.[22] Because there is no underlying lung disease in this series of patients, the treatment was either conservative in the form of spontaneous recovery lasting a few days or chest tube drainage, with a recovery within one week. There were no deaths due to pneumothorax, as has been described in the patients with underlying lung disease, but fatal events can occur in the patients with iatrogenic pneumothorax.[23] However, the majority of pneumothorax complications were caused by thoracentesis or transthoracic needle aspiration, indicating an underlying lung disease. In our report the pneumothorax was solely caused by attempts to puncture the subclavian vein, and it occurred predominantly in the older group of patients with chest deformation. In a case it occurred in a young patient with a pacemaker upgrade (VVI to DDD) or a fracture of the clavicle in the history. It is well known that the pacemaker upgrade has a higher risk compared with a first implantation.[24] The morbidity of pneumothorax itself is low, and full recovery was achieved within a maximum of one week for nonpartial pneumothorax (>10%) and within a few days for partial pneumothorax. ■

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References

1 Bartecchi C. Bedside emergency transvenous cardiac pacing: experience in two community hospitals. *JACEP* 1976;**5**:169-73.
2 Littleford PO, Parsonnet V, Spector SD. Method for the rapid and atraumatic insertion of permanent endocardial pacemaker electrodes through the subclavian vein. *Am J Cardiol* 1979;**43**:980-2.
3 Miller FA, Holmes DR, Gersh BJ, Maloney JD. Permanent transvenous pacemaker implantation via the subclavian vein. *Mayo Clin Proc* 1980;**55**:309-14.
4 Zwirner K. Insertion of permanent endocardial pacing electrodes through the subclavian vein: results of a five-year period. *Z Kardiol* 1980;**69**:835-9.
5 Furman S. Venous cutdown for pacemaker implantation. *Ann Thorac Surg* 1986;**41**:438-9.
6 Fiorista F, Lazari M, Marzegalli M, Piane C, Cotti R, Casazza F, et al. Use of the subclavian vein for permanent cardiac stimulation. *Arch Inst Cardiol Mex* 1986;**56**:309-13.
7 Chauhan A, Grace AA, Newell SA, Stone DL, Shapiro LM, Schofield PM, et al. Early complications after dual chamber versus single chamber pacemaker implantation. *PACE* 1994;**17**:2012-5.
8 Aggarwal RK, Connelly DT, Ray SG, Ball J, Charles RG. Early complications of permanent pacemaker implantation: no difference between dual and single chamber systems. *Br Heart J* 1995;**73**:571-5.
9 Magney JE, Parsons JA, Flynn DM, Hunter DW. Pacemaker and defibrillator lead entrapment: case studies. *PACE* 1995;**18**:1509-17.
10 Kiviniemi MS, Pirnes MA, Eranen HJ, Kettunen RV, Hartikainen JE. Complications related to permanent pacemaker therapy. *PACE* 1999;**22**:711-20.
11 Parsonnet V, Roelke M. The cephalic vein cutdown versus subclavian puncture for pacemaker/ICD lead implantation. *PACE* 1999;**22**:695-7.
12 Calkins H, Ramza BM, Brinker J, Atiga W, Donahue K, Nsah E, et al. Prospective randomized comparison of the safety and effectiveness of placement of endocardial pacemaker and defibrillator leads using the extrathoracic subclavian vein guided by contrast venography versus the cephalic approach. *PACE* 2001;**24**:456-64.
13 Weissberg D, Refaely Y. Pneumothorax. *Chest* 2000;**117**:1279-85.
14 Bernstein AD, Parsonnet V. Survey of cardiac pacing in the United States in 1989. *Am J Cardiol* 1992;**69**:331-8.
15 Belott PH. A variation on the introducer technique for unlimited access to the subclavian vein. *PACE* 1981;**4**:43-8.
16 Tse HF, Lau CP, Leung SK. A cephalic vein cutdown and venography technique to facilitate pacemaker and defibrillator lead implantation. *PACE* 2001;**24**:469-73.
17 Fyke FE 3rd. Doppler guided extrathoracic introducer insertion. *PACE* 1995;**18**:1017-21.
18 Byrd CL. Clinical experience with the extrathoracic introducer insertion technique. *PACE* 1993;**16**:1781-4.
19 Youmans CR Jr, Derrick JR, Wallace JM. Considerations of complications of permanent transvenous pacemakers. *Am J Surg* 1967;**114**:704-10.
20 Molina JE, Dunnigan AC, Crosson JE. Implantation of transvenous pacemakers in infants and small children. *Ann Thorac Surg* 1995;**59**:689-94.
21 Holmes DR Jr. Permanent pacemaker Implantation. Chapter 5. In A practice of Cardiac Pacing. Furman S, Hayes DL, Holmes DR Jr. New York Futira Publishing Company, Inc Mount kiso; 1986:97-127.
22 Tocino IM, Miller MH, Fairfax WR. Distribution of pneumothorax in the supine and semirecumbent critically ill adult. *Am J Roentgenol* 1985;**144**:901-5.
23 Despars JA, Sassoon CS, Light RW. Significance of iatrogenic pneumothoraces. *Chest* 1994;**105**:1147-50.
24 Hildick-Smith DJ, Lowe MD, Newell SA, Schofield PM, Shapiro LM, Stone DL, et al. Ventricular pacemaker upgrade: experience, complications and recommendations. *Heart* 1998;**79**:383-7.
25 Shahian DM, Venditti FJ Jr. Hemothorax associated with anticoagulation after placement of implantable cardioverter defibrillator: possible similarity to postinfarction Dressler's syndrome. *PACE* 1992;**15**:1233-5.
26 Arakawa M, Kambara K, Ito H, Hirakawa S, Umeda S, Hirose H. Intermittent oversensing due to internal insulation damage of temperature sensing rate responsive pacemaker lead in subclavian venipuncture method. *PACE* 1989;**12**:1312-6.
27 Kessinger JM, Holter AR, Geha AS. Implantation of permanent transvenous pacemaker via subclavian vein. *Arch Surg* 1982;**117**:1105-7.
28 Hall JA, Grace AA, Newell SA, Cole T, Schofield PM, Shapiro LM, et al. Prospektive untersuchung der Frühkomplikationen bei 1136 permanenten EinkammerHerzschrittmacher-Implantationen. *Herz-Schrittmacher* 1994;**14**:67-72.
29 Stone C, Aquilina TC, Mangar D, Fonte A. Left infraclavicular brachial plexus block during pacemaker placement through the left subclavian vein. *Anesth Analg* 1994;**78**:602.
30 Szili-Torok T, Klootwijk P, Brand M van den, Ruiter R, Theuns D, Jordaens L. A rare complication: Ossification around the pacing leads after medial subclavian venipuncture. *Cardiologia Hungarica* 2001;**2**:162-4.