S. A. Haje · D. P. Haje

Overcorrection during treatment of pectus deformities with DCC orthoses: experience in 17 cases

Received: 4 November 2005 / Accepted: 22 November 2005 / Published online: 11 February 2006
© Springer-Verlag 2006

Abstract Treatment of pectus carinatum and pectus excavatum with dynamic chest compressor (DCC) orthoses have been reported by Haje and others. The goal of this study was to demonstrate that overcorrection during orthotic treatment of children and adolescents with pectus deformities can occur and requires medical attention. Of 3,028 children and adolescents with pectus deformities, observed between 1977 and October 2005, 1,824 were prescribed treatment with DCC orthoses and, after a few months of treatment, some overcorrection was noted in 30 patients. Of the patients who received orthoses, 738 had a minimum follow-up of one year and 17 of these, two with pectus excavatum and 15 with pectus carinatum, who presented with overcorrection and were studied. The dynamic remodelling method (DCC orthoses + exercises) was applied. The procedures, adopted according to each patient's needs, were: decreasing the time of orthosis wear and/or the tightening of the screws, introducing a second orthosis, and improving the prescribed exercises and/or encouraging the patient to perform them more intensively. The treatment was successful in all patients, and the result was maintained in one case of pectus excavatum followed up until adulthood. It was concluded that overcorrection

during DCC orthosis wear can occur and that careful medical follow-up is necessary if this complication is to be successfully reversed.

Résumé Le traitement du pectus carinatum et du pectus excavatum avec une orthèse dynamique (DCC) a été rapporté par Haje et coll. Le but de cette étude est de montrer que l'hypercorrection est possible. Sur 3028 enfants et adolescents atteints de déformation pectorale, observés entre 1977 et 2005, 1824 ont eu un traitement par orthèse DCC et une hypercorrection a été noté chez 30 patients. Parmi les patients traités 738 ont un suivi minimum d'un an et 17 d'entre eux (2 pectus excavatum et 15 pectus carinatum), ont une hypercorrection. Le traitement (orthèse + exercices), adapté à chaque patient était : diminution du temps de port de l'orthèse et/ou resserrage des vis, utilisation d'une seconde orthèse et stimulation du patient pour augmenter l'intensité des exercices. Des améliorations étaient obtenues dans tous les cas et, dans un cas de pectus excavatum, maintenues jusqu'à l'âge adulte. Il est conclu que l'hypercorrection peut survenir durant le port de l'orthèse DCC et que pour la contrôler une surveillance médicale soigneuse doit être faite.

S. A. Haje
Department of Paediatric Orthopaedics,
Centro Clínico Orthopectus,
Hospital Regional da Asa Norte,
Secretaria de Estado da Saúde do Governo do
Distrito Federal, Brasília, Brazil

D. P. Haje
Department of Paediatric Orthopaedics,
Centro Clínico Orthopectus,
Hospital de Base do Distrito Federal,
Secretaria de Estado da Saúde do Governo do
Distrito Federal, Brasília, Brazil

S. A. Haje (✉)
SHIS QL 12 conjunto 10 casa 18,
71630-305 Brasília, DF, Brazil
e-mail: orthohaje@orthopectus.com.br
Tel.: +55-61-3425-1408

Introduction

Some authors reported corrective casting and/or bracing with straps involving the thorax as effective for children with pectus carinatum in the 1960s and 1970s [2, 18, 19, 21]. In 1993, Mielke and Winter described the case of a female adolescent with pectus carinatum successfully treated by means of an underarm body cast followed by the use of a brace made of plastic shells and straps involving her thorax and shoulders [20]. Beirão, in 1999, reported good results for 50 patients with pectus carinatum treated using the dynamic chest compressor (DCC) orthosis [1], first described by Haje et al., in 1979 and 1988, for pectus carinatum deformities [4, 5]. Since 1992, Haje et al. have described treatment with DCC orthoses not only for pectus carinatum, but also for pectus excavatum [6, 7, 9, 10, 12, 15, 16].

The pectus deformities of the sternal area are normally divided into carinatum, to designate a protrusion, and excavatum, to designate a depression. A subclassification of these deformities into pectus carinatum superior (PCS), pectus carinatum inferior (PCI), pectus carinatum lateral (PCL), pectus excavatum wide (PEW) and pectus excavatum localized (PEL) was described by Haje et al., who also described the occurrence of mixed types, with the predominant type being used to designate the deformity [14, 16]. Flexibility is more important than the severity of the deformity for predicting the outcome of treatment. The clinical tests to check the flexibility of the deformities are the manual compression test or carinatum flexibility test and the increased intrathoracic pressure test or excavatum flexibility test, described by Haje and Bowen [6]. The PCI and PCL types of pectus carinatum are usually flexible, while the PCS is rigid and more difficult to treat orthotically. The PEW is usually more flexible than the PEL. The dynamic remodeling (DR) method is a term created to designate the practice of exercises that increase the intrathoracic pressure along with the use of DCC orthoses under medical supervision [16]. Haje described 565 children and adolescents treated by such a method, with good or excellent results for 89% of the more common and flexible types of pectus carinatum (PCI and PCL), good results for 30% of the less common and less flexible PCS, and good results for 32% of pectus excavatum (PEW and PEL) [16].

Complications from the orthotic treatment are not common. Haje and Bowen reported a slight or moderate skin rash on the sites of compression by the pads of the DCC as the only complication of such treatment [6]. The possibility of overcorrection in flexible types of pectus carinatum has been described, but not studied in detail [9, 16]. The purpose of this paper is to report a study on overcorrection of pectus and the clinical measures adopted for its reversal, and also to demonstrate that this complication can occur not only in pectus carinatum, but also in

flexible pectus excavatum deformities during treatment by the DR method.

Materials and methods

Of 3,028 children and adolescents with pectus deformities, observed between 1977 and 2005, 1,824 were prescribed treatment with DCC orthoses and, after a few months of treatment, some overcorrection was noted in 30 patients. Of the patients who received orthoses, 738 had a minimum follow-up of one year and 17 of these, two with pectus excavatum and 15 with pectus carinatum, presented with overcorrection and were selected for study. The DR method was used: regular daily exercises were prescribed to increase the intrathoracic pressure, along with the wearing of one or two DCC orthoses [9, 16]. The principal exercises were blowing balloons and doing sit-ups, push-ups, and exercises in an apparatus called “peck-deck” (Fig. 1). Back-stroke and free-style swimming was the only physical activity prescribed without the orthosis. A plaster cast mould was always used to produce customised orthoses [9, 16] (Fig. 2). Data on the type of pectus, sex, age at beginning of treatment, time required for detection of overcorrection, procedure, follow-up and outcome were collected (Table 1). The requirement for an extensive period of treatment (at least 1 or 2 years) and the necessity of wearing the orthosis as much as possible according to each stage of treatment were stated to all patients as important factors for a successful treatment. In the first few months of treatment: two to three months for carinatum and five to six months for excavatum deformities. All patients were instructed to wear the orthosis for 21 h daily, including the sleeping period, removing the orthosis only for showering, swimming and sports. A gradual weaning from the orthosis was recommended thereafter, depending on each patient’s progress. Adjustments in the orthoses

Fig. 1 Patients wearing DCC I and DCC II orthoses while doing exercises that increase the intrathoracic pressure. The DCC I is the superior orthosis and the DCC II the inferior one, with two anterior pads. The exercises shown are: **a** blowing up a balloon; **b** sit-ups with 45° of trunk elevation with the cervical spine straight; **c** arm adduction against resistance in a “peck-deck” apparatus

Fig. 2 PCI patient **a** before treatment and **b** overcorrected after 2 months of DCC I wear, with exacerbation of inferior rib flaring. **c, d** The patient received a plaster cast mold for construction of a customized DCC II orthosis. Note that the patient wears the original orthosis (DCC I) under protective clothing while the mold is made for the second one (DCC II)

were often required, and sometimes a new customised orthosis had to be made during the course of treatment because of changes in the thorax shape due to remodelling and/or growth. Clinical photographs taken from the same angles before and during treatment were used for clinical evaluation of the results.

When overcorrection was noted, one of the following procedures was adopted: (1) For pectus carinatum: (a) decrease in time wearing the DCC I and/or decrease in tightness of the screws; (b) temporary suspension of DCC I

wear (for one week to one month, according to the severity of overcorrection), followed by use of the orthosis for a shorter time, with controlled screw tightening; (c) decrease in time wearing the DCC I and/or decrease in tightness of the screws, or temporary suspension of orthosis wear, with introduction of a second orthosis, DCC II, during treatment. (2) For pectus excavatum: (d) decrease in time wearing the DCC II and/or in tightness of the screws; (e) decrease in time wearing the DCC II and/or in tightness of the screws and introduction of a second orthosis, DCC I,

Table 1 Patient's progress

Patient	Type of pectus	Sex	Decimal age (years) at beginning of treatment / type of DCC	Period of treatment before diagnosis of overcorrection	Procedure*	Duration of follow-up / end result*
1	PEW	M	12.41 / DCC II	5 mo.	e	8 y.+4 mo. / 3
2	PEW	F	12.16 / DCC II	6 mo.	d	2 y. / 1
3	PCI	F	11.58 / DCC I	2 mo.	b	2 y.+8 mo. / 2
4	PCI	M	13.08 / DCC I	2 mo.	c	2 y.+1 mo. / 2
5	PCI	M	13.08 / DCC I	2 mo.	b	1 y.+8 mo. / 2
6	PCI	M	15.58 / DCC I	2 mo.	a	2 y.+3 mo. / 2
7	PCI	M	13.16 / DCC I	2 mo.	c	1 y.+7 mo. / 2
8	PCI	F	10.58 / DCC I	2 mo.	a	1 y.+7 mo. / 2
9	PCI	M	14.50 / DCC I	2 mo.	c	1 y.+8 mo. / 2
10	PCI	M	15.33 / DCC I	2 mo.	c	1 y.+11 mo. / 2
11	PCI	M	14.08 / DCC I	2 mo.	a	1 y. / 1
12	PCI	F	8.66 / DCC I	2 mo.	a	1 y. / 1
13	PCI	M	13.08 / DCC I	2 mo.	a	1 y.+2 mo. / 1
14	PCI	M	14.66 / DCC I	2 mo.	c	1 y.+8 mo. / 1
15	PCI	M	14.75 / DCC I	1 mo.	a	1 y.+1 mo. / 1
16	PCI	M	13.75 / DCC I	2 mo.	a	1 y. / 1
17	PCL	M	12.50 / DCC I	2 mo.	a	1 y. / 1

*See explanation of procedures and results in last two paragraphs of [Materials and methods](#)

Fig. 3 PEW patient (case 1 in Table 1). **a** Before treatment. **b** Overcorrection was seen after 5 months of continuous wear of a DCC II and over enthusiastic dedication to the exercise program of the DR method. **c** Clinical appearance after 6.5 years of treatment, which also included a DCC I orthosis

during treatment. All pectus carinatum patients received instruction for improvement and intensification of exercises along with orthosis wear. The two pectus excavatum patients were prescribed a small decrease in the intensity of the exercise program.

The following scale of results at last visit was used to define the level of improvement compared to the initial deformity: 1 = no overcorrection, recurrence of slight initial deformity; 2 = no overcorrection, no recurrence of initial deformity and stable after at least one month without the orthosis; 3 = no overcorrection, no recurrence of initial deformity and stable after at least one year without the orthosis.

Results

From 17 children and adolescents, 13 males and four females, who developed overcorrection during treatment by the DR method, two had PEW, 14 PCI and one PCL. Their mean age at the beginning of treatment was 13 years, 1 month (range 8 years, 9 months to 15 years, 7 months), and the mean duration of follow-up was two years (range 12 months to 8 years, 4 months). Overcorrection was observed in the two pectus excavatum patients between the fifth and sixth months and in all pectus carinatum patients in the first or second month of treatment. A patient with pectus excavatum (case 1 in Table 1), who had reached maturity when last seen, presented a result of level 3. This patient started the DR method in early adolescence (12 years, 5 months) and exhibited great willpower with regard

to orthosis wear and exercises. The first orthosis worn was a DCC II, and after five months of treatment a slight protrusion in the median area of the sternum was noted. The patient was instructed to decrease the daily time of orthosis wear and to decrease the intensity of the prescribed exercises, but he did not follow these instructions and kept the exercise program at the same intensity. After 13 months of treatment a DCC I was added. The patient was instructed to wear the DCC I at night, the DCC II during the day, and both orthoses for the prescribed exercises. As we were observing a progressive remodelling of the anterior chest wall, a gradual weaning from the orthoses was authorized. After 3.5 years, the patient was authorized to wear the orthoses only when performing the exercises. Four and a half years after the beginning of treatment he was authorized to stop using the DCC I, and after 6.5 years the DCC II was discontinued (Fig. 3). The correction was maintained at age 20 years, 9 months, i.e., 8 years and 4 months after treatment began and 21 months after discontinuing the orthosis. The second patient displaying pectus excavatum with overcorrection (case 2 in Table 1) was a female who also started the DR method in early adolescence (12 years, 2 months), but who had enough will power for orthosis wear and for exercising only in the first 6 months of treatment, when a slight protrusion in the median sternal area was noted. After being told to decrease the daily time of DCC II orthosis wear and to decrease the intensity of prescribed exercises, she exceeded her instructions. When she was last seen after two years of treatment, a slight recurrence of the excavatum deformity had taken place, though not as much as the initial deformity. She did not

Fig. 4 PCI patient (case 3 in Table 1). **a** Before treatment. **b** Overcorrection seen after 2 months of continuous wearing of a DCC I, with insufficient dedication to the exercise program. **c** Clinical aspect after 2 years of treatment, with periods without the orthosis

need a DCC I orthosis. However, she was advised to wear the original DCC II orthosis more regularly and to practice the exercises more intensively and regularly.

Eight cases of PCI presented an improvement of level 2 when last seen, showing an apparently stable correction after a period of at least one month without the orthosis. An example is patient 3 in Table 1, in whom overcorrection was seen after two months of continuous DCC I wear and less than ideal adherence to the exercise program. The patient was then instructed to suspend temporarily the wearing of the orthosis. At three months of treatment, after one month without the orthosis, a slight protrusion recurred, upon which the DR method was recommenced with the DCC I worn for 12 h a day. After ten months of treatment the patient was allowed to wear the orthosis for only two hours a day. One year after the first visit DCC I wear was discontinued, but after 17 months a very slight protrusion was noted and she returned to wearing the orthosis only for sleeping and during the exercises. Her dedication to the exercises was not good at the beginning, but improved during treatment. Two years after the first visit she was finally released from the orthosis (Fig. 4). No signs of overcorrection or of recurrence of the initial deformity were noted when she was last seen, 32 months after the beginning of treatment and 8 months after she was released from the orthosis.

Seven patients with pectus carinatum (six PCI and one PCL) presented a result of level 1 without overcorrection when last seen, but with a trend towards recurrence of a slight protrusion, in most cases insignificant. An example is patient 11 in Table 1. His overcorrection was seen two months after continuous wear of a DCC I and little dedication to the exercises. The patient was instructed to decrease the daily period of DCC I wearing from 23 hours to four hours, to decrease the tightness of the screws and to intensify the exercise program. He followed our instructions less closely than he should have done and wore the orthosis for just one hour, for the exercises that he informed us he practiced twice a week. Twelve months after the beginning of treatment the recurrence of a slight protrusion could be seen (Fig. 5).

Some patients with overcorrected PCI, who already had depression of some lateral costal arches and flaring of the lowest ribs, showed an increase in rib flaring with the wear of the DCC I, necessitating the inclusion of a DCC II in the treatment (cases 4, 7, 9, 10 and 14 in Table 1).

Discussion

Overcorrection of pectus excavatum during a conservative treatment is something new, as there is a general belief that the simple improvement of an excavatum deformity would be impossible without surgery. The two such cases reported in this study indicate that these deformities can be treated through the balance of forces. The gradual external effect of a DCC II orthosis on the flaring of the inferior ribs and the increase in the intrathoracic pressure provoked by the exercises provide an effective internal pressure on the depressed central area. The continuation of such a program over a long period results in a remodelling process based on Wolff's law, similar to the one observed in orthodontic treatments.

Reports that condemned the nonoperative treatment of pectus carinatum as noneffective [17] were contradicted by publications describing good results in adolescents treated orthotically, with maintenance of the outcome into adulthood [5, 6, 9, 16, 20]. The treatment period for stable correction of a flexible pectus carinatum deformity with the DR method is reported to be from eight months to two years, but it can be longer if the patient does not follow all medical instructions [9, 16]. None of the PCI and PCL patients in this study had reached adult life at the end of observation, and the purpose of their inclusion in this study is mainly to demonstrate the measures for resolution of an overcorrection without risk of recurrence of the initial deformity. All of the PCI and PCL patients had good anterior chest wall flexibility, but poor will power in performing the prescribed physical exercises.

Chest computed tomography (CT) has been reported as a way to quantify pectus deformities. Egan et al. used CT to study five patients with pectus carinatum treated with

Fig. 5 **a** Before treatment. Patient with moderate PCI (case 11 in Table 1). **b** Overcorrection was seen after 2 months of continuous wearing of a DCC I, with insufficient dedication to the exercise program. The patient decreased the period of orthosis wearing more

than we had recommended and exercised less than we had prescribed. **c** The clinical aspect of slight protrusion recurrence, 12 months after beginning of treatment

compressive orthosis and concluded that compressive orthoses have a potential role in the management of pectus carinatum, suggesting CT as an objective radiographic marker, that may be used to monitor the effects of growth or treatment with compressive orthoses [3]. Previously, Haje had demonstrated by CT the improvement of a pectus carinatum deformity treated by the DR method [9, 10]. Some authors have simply used photographs to document pectus deformities [4–8, 11–16, 20, 22]. Clinical photographs, used in this study, were found by the authors to represent a simpler, more efficient, harmless and less expensive method of evaluating a pectus deformity. Pectus carinatum and excavatum are complex deformities anatomically subdivided into several and sometimes mixed types of various degrees of severity. Photographic documentation is, therefore, the ideal method to demonstrate the protrusion and depression components of a given deformity.

Wong and Carter suggest that mechanical forces may strongly influence skeletal morphogenesis, growth and development, and that corrective measures may change the stress histories to alter subsequent patterns of growth and ossification beneficially [23]. We see overcorrection during the DR method as part of such a process. Treatment should not be interrupted and the patient should not be discharged when overcorrection is first noted. The initial deformity will surely return in this situation, especially in immature patients. Treatment with DCC orthoses is a medical procedure and overcorrection must always be considered, especially in patients with flexible deformities who are highly motivated. Proper medical supervision can lead to the best outcome for a pectus deformity treated by the DR method.

References

1. Beirão ME (1999) Tratamento conservador do pectus carinatum com uso de órtese. *Rev Bras Ortop* 34:575–578
2. Bianchi C et al (1968) Risultati a distanza su 20 casi di “Cifosi Sternale” tratti incruentamente. *Fracastoro* 61:779–792
3. Egan JC, DuBois JJ, Morphy M, Samples TL, Lindell B (2000) Compressive orthotics in the treatment of asymmetric pectus carinatum: a preliminary report with an objective radiographic marker. *J Pediatr Surg* 35(8):1183–1186 Aug
4. Haje SA, Raymundo JLP (1979) Considerações sobre deformidades da parede torácica anterior e apresentação de tratamento conservador para as formas com componentes de protrusão. *Rev Bras Ortop* 14(4):167–178
5. Haje SA, Antunes EJ, Raymundo JLP, Dourado JN (1988) Pectus Carinatum: enfoque atual. *Rev Bras Ortop* 23(9):257–264
6. Haje SA, Bowen JR (1992) Preliminary results of orthotic treatment of pectus deformities in children and adolescents. *J Pediatr Orthop* 12(6):795–800, Nov–Dec
7. Haje SA (1993/94) Pectus deformities from an orthopaedic standpoint. In: *Orthopaedic Transactions of the Sixtieth Annual Meeting of the American Academy of Orthopaedic Surgeons*, San Francisco, California, Feb 1993. *J Bone Joint Surg Am* 17(4):977–897
8. Haje SA (1995) Deformidades *pectus*: novos conceitos e abordagem ortopédica em crianças e adolescentes - 1ª parte. *Rev Bras Ortop* 30(1,2):75–79
9. Haje SA (1995) Deformidades *pectus*: novos conceitos e abordagem ortopédica em crianças e adolescentes - 2ª parte. *Rev Bras Ortop* 30(3):143–149
10. Haje SA (1995) Pectus carinatum successfully treated with bracing—a case report. *Int Orthop* 19(5):332–333 Letter to the Editor
11. Haje SA (1995) Iatrogenic pectus carinatum. A case report. *Int Orthop* 19(6):370–373
12. Haje SA (1996) Pectus carinatum iatrogênico (pós-cirurgia cardíaca pediátrica): resultados do tratamento ortopédico-ortopédico-fisiológico. *Bras Med* 33:93–99
13. Haje SA, Bowen JR, Harcke HT, Guttenberg ME, Bacon CR (1998) Disorders in the sternum growth and pectus deformities: an experimental model and clinical correlation. *Acta Ortop Bras* 6:67–75
14. Haje SA, Harcke HT, Bowen JR (1999) Growth disturbance of the sternum and pectus deformities: imaging studies and clinical correlation. *Pediatr Radiol* 29:334–341
15. Haje DP, Haje SA, Simioni MA (2002) Prevalência das deformidades pectus carinatum e pectus excavatum em escolares do Distrito Federal. *Bras Med* 39:10–15
16. Haje SA (2003) Tórax e cintura escapular. In: Hebert SK, Xavier R, Pardini AG Jr, Barros Fo TEP. *Ortopedia e traumatologia: princípios e prática*, 3rd edn. Artmed, Porto Alegre, pp 161–184
17. Howard R (1958) Pigeon breast (protrusion deformity of the sternum). *Med J Aust* 45:664–666
18. Jaubert de Beaujeu M et al (1964) Thorax en careen. *Lyon Chir* 60:440–443
19. Lange M (1969) Torax. In: *Afecciones del aparato locomotor*. Trad. De Jaime Profits Palou, Barcelona, Jims 2:543–544
20. Mielke CH, Winter RB (1993) Pectus carinatum successfully treated with bracing. A case report. *Int Orthop* 17(6):350–352 Dec
21. Müller W (1973) Deformidades torácicas. In: Chapchal G, Waigand D (eds) *Terapêutica ortopédica*. Trad. De Jorge Ballester Soleda, Barcelona, Salvat 376–384
22. Ravitch MM (1977) Congenital deformities of the chest wall and their operative correction. Saunders, Philadelphia
23. Wong M, Carter DR (1988) Mechanical stress and morphogenic endochondral ossification of the sternum. *J Bone Joint Surg Am* 70:992–1000