Comparison of conservative management and juvenile pubic symphysiodesis in the early treatment of canine hip dysplasia

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Summary

Objectives: To evaluate the efficacy of juvenile pubic symphysiodesis (JPS) in a clinical setting for the early treatment of canine hip dysplasia (CHD), and to identify its indications and contraindications. Methods: The final degree of CHD using the FCI (Fédération Cynologique Internationale) CHD classification in 5 Grades (A, B, C, D, E) was assessed at skeletal maturity in two homogeneous groups of dogs assessed at the age of 14 to 22 weeks and selected according to their susceptibility to CHD; one group was treated with JPS and one group was conservatively managed. Two hundred seventeen puppies completed the study; 81 were treated with JPS (group 1) and 76 were conservatively managed (group 2). A third group of 60 puppies with normal hips was followed as a negative control group. Results: In group 1, 43.2% of the puppies had regression or a lack of progression of the disease in the final evaluation (Grade A & B), 25.9% had mild CHD (Grade C) and 30.9% had moderate and severe CHD (Grade D & E). In group 2, 23.6% of the puppies did not show any development of the disease (Grade A & B), 21.1% had mild CHD (Grade C) and 55.3% developed moderate to severe CHD (Grade D & E). Further investigation was done by comparing the severity of early signs of susceptibility to CHD with the final FCI Grades at adulthood in both groups. Clinical significance: The JPS procedure increased the odds of arresting or limiting the progression of CHD in mild to moderate grades of CHD, while it was less effective or ineffective in more severe forms.

Keywords
Dog, hip dysplasia, CHD, juvenile pubic symphysiodesis, JPS


Introduction

Canine hip dysplasia (CHD) is the most frequent non-traumatic orthopaedic pathology found in growing dogs. It is characterised by a lack of congruity between the articular surfaces of the femoral head and the acetabular cavity, which inevitably leads to osteoarthritis (OA) (1–4). With early accurate diagnosis in the growing puppy (4–11), it is possible to intervene in dysplastic evolution with prophylactic type surgical procedures, such as juvenile pubic symphysiodesis (JPS) (12–16) and triple pelvic osteotomy (TPO) (17–20). The aim of these surgical treatments, which are carried out during the phase of skeletal development of animals showing signs of susceptibility to CHD, is to arrest the progression of the disease by reversing the tendency to subluxation, and avoiding or limiting the development of secondary OA (11–16, 18–20). The fundamental principle on which the JPS and TPO procedures arebased is the neutralisation of forces that tend to make the hip subluxate by modification of the dorsal acetabular rim angle (DARA) (19, 20). It is well known that an increase in the DARA brings about progressive coxofemoral subluxation with erosion of articular cartilage, especially if associated with excessive articular laxity, increase in the growing dog’s weight and physical activity (21–23). The JPS procedure, which was recently introduced as an early treatment for dysplastic puppies, has proved to be, in both experimental works as well as in clinical studies, a surgical procedure that can correct or limit the development of initial forms of CHD and therefore prevent secondary OA (12–16, 18). However, in the most advanced forms of CHD in young puppies, JPS has proven to be ineffective in the prevention of coxofemoral subluxation during weight bearing and the resulting dysplastic joint degeneration (16). The JPS technique consists of electrocauterization of physeal cartilage of the pubic symphysis, inducing thermal necrosis of the germinal chondrocytes and arrest of endochondral bone growth. Premature closure of the pubic symphysis during the puppy’s growth causes medial – lateral shortening of the cranial ramus pubicus, resulting in limitation of the circumferential growth of the ventral part of the pelvic girdle. This arrest of ventral growth of the pelvis, associated with free growth of the dorsal component, leads to ventral traction on the acetabulum and outward rotation of the acetabular rim. The acetabular ventroflexion obtained with JPS leads to diminution of the DARA and improvement of joint congruity and therefore greater acetabular coverage of the femoral heads (Fig. 1) (12–16). Encouraged by these studies carried out by other authors, we wanted to carry out a prospective clinical study in order to evaluate the efficacy of JPS in field conditions and with a large cohort of dogs with early signs of susceptibility to CHD. A further aim of the study was to investigate the limitations of applicability, the indications, contraindications and complications of this surgical technique. Consequently, the aim of the clinical study was also to define indications for formulating a reliable prognosis in relation to the clinical and radiographic data gathered in the preoperative evaluations. JPS must be performed as early as possible because its thera-
apeutic potential is achieved during growth (10, 15), hence early and accurate clinical and radiographic evaluations of the hips of puppies between 14 and 22 weeks were necessary (3).

Materials and methods

Study design

A prospective study was carried out with longitudinal analysis of puppies of different breeds aged between 14 and 22 weeks that had initial physical or radiographic signs of susceptibility to CHD, during the three year period between January 2003 and December 2006. The study was followed up to adulthood of at least 12–18 months of age, with a final classification of the CHD degree according to FCI Classification in 5 Grades. Puppies were also included that did not yet have clinical signs referable to CHD, but which at early evaluation – with palpation (20) of the hips and a radiographic study (21) – were positive to diagnostic tests indicative of initial forms of CHD or of susceptibility to CHD, such as positivity of the Ortolani sign (22) and increase of the distraction index (24–30) and subluxation (18, 31). The puppies included in the study were divided into two homogeneous groups of patients in the same initial conditions: group 1 comprised puppies that subsequently underwent JPS operations, while the group 2 puppies were treated conservatively. Both groups of puppies were followed up until completion of skeletal development. The allocation of puppies to groups was not randomized, but depended on the owner’s decision to have JPS performed, once the initial signs of susceptibility to CHD had been identified and the operation suggested. A written informed consent form was obtained from owners to ensure full understanding of the potentially poor results of both JPS and conservative management. For the puppies that were to undergo the JPS operation, the informed consent form also included a commitment by the owner to not use his dog in the future for reproductive purposes. At the same time surgical sterilisation was advised. The puppies of each group were further divided into three subgroups according to the severity of the detected signs of susceptibility to CHD (Figs. 2, 3, 4). Subdivision into three degrees of severity also meant that the groups were as homogeneous as possible for initial joint conditions in order to be able to correlate the severity of early signs with the degree of CHD reached on termination of growth. In this way a more reliable prognosis for JPS could be formulated on the basis of the parameters obtained during early diagnosis.

An additional group 3 was included in the study, which consisted of puppies that had demonstrated normal joints at early evaluation of their hips (Fig. 5), with negativity in the diagnostic tests indicative of susceptibility to CHD. They were followed up to adulthood without any treatment in order to provide a negative control group. Those puppies with advanced signs of the pathology and/or clinical signs were excluded from the study because JPS had already been shown to be inefficacious in such cases (16).
Diagnostic procedures

For early evaluation of the hips the puppies underwent sedation by IM administration of acepromazine maleate\textsuperscript{a} (15 mcg/kg) and atropine sulphate\textsuperscript{b} (20 mcg/kg) and were subsequently anaesthetised with an intravenous injection of fentanyl\textsuperscript{c} (8 μg/kg). Each patient underwent a clinical examination consisting of palpation of each joint with evaluation of the Ortolani sign and measurement of the reduction and subluxation angles as follows: Ortolani sign, evaluated as positive or negative, with the puppy in dorsal recumbency (22). Angle of reduction (AR) and subluxation (AS) measured with a Slocum Electronic Gonimeter\textsuperscript{©} (Slocum Enterprises Inc., Eugene, OR, USA) (22) with the puppy in the same position. Three measurements were taken for each coxofemoral joint and the mean value noted.

Static and dynamic radiographic studies were then carried out and these included the following views: standard ventral-dorsal view with extended limbs, distraction view and DAR (dorsal acetabular rim) view.

In the standard ventral-dorsal radiographic view that was obtained with maximum attention to symmetry, joint morphology was evaluated by observing the acetabular coverage of the femoral head, articular congruity and degree of subluxation. In order to standardise a method for evaluation of articular congruity and to make it applicable to all patients in the growth period it was decided to evaluate the position of the centre of the femoral heads with regard to the superimposed dorso-lateral acetabular rim and to classify it as follows: centre of the femoral head medial to the dorso-lateral acetabular rim; centre of the head superimposed over the dorso-lateral acetabular rim; and centre of the femoral head lateral to the dorso-lateral acetabular rim with related measurement of the millimetres of distance from it. Measurement of the Norberg angle, which is commonly used in adults, is not suitable when applied to 14–22 week-old puppies since the effective cranial-lateral edge of the acetabulum, which is used as a reference for measuring the Norberg angle, still has a cartilaginous component which prevents precise identification. Vice-versa, normal articular congruity is well verified by the positioning of the femoral head which must be centred in the acetabulum and with its centre positioned medially to the dorso-lateral acetabular rim. A careful evaluation was then carried out for any morphological modifications of the acetabular borders and of the articular heads and signs of OA such as subchondral sclerosis, Morgan’s line, and osteophytes on the femoral head and neck (1–4). Distraction radiographic view in accordance with the method described by R. Badertscher (31) was performed with a distractor modified by one of the authors (AV) and produced by FSA (FSA, Palazzo Trecchi, Cremona, Italy) (3). The measurements described by Smith and colleagues (24–29)
were carried out on the radiographs to obtain the distraction index (DI) of each joint. The DAR view was obtained in order to measure the slope of the dorsal acetabular rim (DAR = DAR angle) on the radiographs using the technique described by Slocum and his sliding goniometer (21, 23), as well as to evaluate the integrity or erosion of the lateral extremity of the DAR.

Case selection method

Groups 1 and 2 included puppies showing signs of susceptibility to CHD such as, positive Ortolani sign, AR between 15° and 45°, AS between 0° and 15°, centres of the femoral heads situated in correspondence to the DAR or lateral to it in the standard ventral-dorsal view, distraction index between 0.4 and 0.9 and DAR slope between 7° and 12° with well preserved DAR lateral margin. Group 3 included puppies with normal coxofemoral joints, negative Ortolani sign (or slightly positive with AR < 10° and AS 0° or < 0°), centre of the femoral head medial to the DAR, DAR angle < 7°, distraction index < 0.4 (Fig. 5). The puppies with more severe signs of CHD were excluded whether these signs were associated with clinical signs or not, such as lateral erosion of the lateral margin of the DAR, a slope greater than 12°, an AR greater than 45° with distraction index greater than 0.9, an AS greater than 15°, because all of these signs are indicative of a dysplastic process that is already advanced and can not be modified efficiently with this surgical technique (31, 33) (Fig. 6). Since the early signs of CHD appear in a quantitative manner, the puppies of groups 1 and 2 were further subdivided into 3 subgroups with different degrees of severity of the observed clinical and radiological values (α = minor, β = intermediate and γ = major) (Table 1, Figs. 2, 3 and 4). In the evolution of CHD the values of the various clinical and radiological parameters were generally reciprocally correlated and therefore distributed within three sub-groups as shown in Table 1. When the individual parameters fell into more than one sub-group, the most severe grouping was assigned. Also, in cases where the values of one hip were different from the contralateral hip, the worse hip was decisive.

Animals

Five hundred fifty-three puppies were enrolled in the study, 172 of which underwent the JPS operation (group 1) and 14 of which were also spayed during the same operation. One hundred eighty-eight were treated conservatively (group 2), and the 193 puppies with normal coxofemoral joints were assigned to group 3. In total, 217 puppies (39%) fully completed the subsequent re-checks until skeletal maturity; of which 81 had been treated with JPS (group 1), 76 conservatively (group 2) and 60 were from group 3. Of the remaining 91 patients in group 1, 78 underwent only the first recheck two to four months after the operation and 13 were not brought back for the recheck. Of the remaining 112 puppies in group 2, 52 underwent only the first recheck and 60 were not brought back for any recheck at all. Although the two to four month rechecks could already supply important data on treatment efficacy, they were not included in the study since the aim was to carry out a long-term evaluation until completion of skeletal development. However, the results of the first two to four month recheck turned out to be in line with those of the last recheck carried out after skeletal maturity was reached.

The average age of the 81 dogs that were treated surgically and followed up until the
second recheck, or those that underwent other surgical operations after the first recheck (group 1), was 16.8 weeks. 50 were male and 31 female, belonging to the breeds listed in Table 2. Of the 76 puppies that were treated conservatively and followed up until the final recheck, or that underwent further surgical operations after the first recheck (group 2), the average age was 17.4 weeks, 40 were male and 36 female. The breed distribution is listed in Table 2.

Of the 60 puppies in group 3, which at early evaluation of the hip joint showed no initial signs of CHD, the average age was 16.6 weeks; 31 were male and 29 female, belonging to the breeds listed in Table 2.

**Surgical procedure**

The surgical procedure of JPS was carried out with the patient under general anaesthesia. After pre-medication with acepromazine\(^d\) (15 μg/kg) and induction with fentanyl\(^f\) (4 μg/kg) and propofol\(^g\) (4 mg/kg IV), anaesthesia was maintained with isoflurane\(^e\) 1.2 MAC (1.2%) and fentanyl infusion\(^c\) (2–4 μg/kg/hr). Cefazolin\(^f\) (20 mg/kg IV), was administered perioperatively antibiotic prophylaxis and morphine\(^e\) (0.15 mg) for postoperative analgesia. A low dose of metilprednisolone\(^h\) (0.2 mg/kg IV) was administered at the induction time in order to minimize tissue inflammation. A mid-ventral skin incision of 3–5 cm was made over the proximal part of the pubis which was identified through palpation of the pubic tubercle. The skin incision was followed by blunt and sharp dissection of the subcutaneous tissues on the median line to permit visualisation of the insertion of the pre-pubic tendon on the median pubic tubercle. After a short transversal incision of the tendon a finger or a wooden spatula was inserted beneath the symphysis in order to protect the underlying organs, especially the urethra and rectum, and to avoid them from being damaged by subsequent electrocauterization. Electrocauterization of the cartilaginous structures of the pubic symphysis was generally carried out with a radio frequency electrosurgical unit adjusted to a delivery of 50 watts in coagulation mode, using a spatula electrode with continuous action of seven to eight seconds for each cauterization; in some cases a standard electrosurgical unit was used, adjusted to the same delivery power. The procedure was carried out starting from the cranial margin for a distal length of 12–25 mm in such a way as to involve the part of the symphysis that originates the cranial pubic rami (Fig. 7). The electrode was inserted full thickness into various points of the cartilage until it touched the wooden spatula beneath, along both osteo-cartilaginous margins. Each individual cauterization was carried out at a distance of about 2–3 mm from the previous.

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\(^a\) Propofol, B Braun, Melsungen AG, Germany.
\(^b\) Isoba Schering-Plough Animal Health S.p.A., Milan, Italy.
\(^c\) Cefazolin DOROM S.r.l, Milan, Italy.
\(^d\) Morfina cloridrato Molteni S.p.A., Scandicci (FI) Italy.
\(^e\) Urbason Sanofi-Aventis S.p.A., Milan, Italy.

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**Table 1** Degrees of severity (α, minor; β, intermediate and γ, major) of the susceptibility signs for CHD: criteria for inclusion of each dog at enrollment of the susceptibility signs for CHD: criteria for inclusion of each dog at enrollment.

<table>
<thead>
<tr>
<th>Degrees of severity</th>
<th>AR</th>
<th>AS</th>
<th>DI</th>
<th>DARA</th>
<th>Centres of the femoral heads</th>
</tr>
</thead>
<tbody>
<tr>
<td>α minor</td>
<td>15°–25°</td>
<td>0°–5°</td>
<td>0.4–0.6</td>
<td>7°–10°</td>
<td>over DARA – lat. 1 mm</td>
</tr>
<tr>
<td>β intermediate</td>
<td>26°–35°</td>
<td>6°–10°</td>
<td>0.61–0.75</td>
<td>7°–12°</td>
<td>over DARA – lat. 2 mm</td>
</tr>
<tr>
<td>γ major</td>
<td>36°–45°</td>
<td>11°–15°</td>
<td>0.76–0.9</td>
<td>10°–12°</td>
<td>lat. 2–3 mm</td>
</tr>
</tbody>
</table>

**Table 2** Breed distribution among the three groups of dogs.

<table>
<thead>
<tr>
<th>Breed</th>
<th>Group 1 JPS treatment</th>
<th>Group 2 Conservative management</th>
<th>Group 3 Negative control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labrador Retriever</td>
<td>38</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>Golden Retrievers</td>
<td>21</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>German Shepherd Dog</td>
<td>7</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Cane Corso</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Bernese</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Border Collie</td>
<td>1</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Dogue de Bordeaux</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Boxer</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Russian Terrier</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mastiff</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>English Setter</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Charplanina Shepherd Dog</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Newfoundland</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Rottweiler</td>
<td>-</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Mongrel</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Caucasian Shepherd Dog</td>
<td>-</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Dobermann</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Czech Wolf</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Belgian Shepherd Dog</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Hovawart</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>Australian Shepherd Dog</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
</tbody>
</table>
one and was followed by a saline irrigation to cool the surrounding tissues. The detached portion of the pre-pubic tendon was sutured to the periosteum with interrupted sutures using absorbable material, the subcutaneous layers were closed with the same material with two continuous sutures, one deep and one superficial, followed by suture of the skin with interrupted stitch knots in nylon. The entire procedure took 20–30 minutes and the puppies were sent home the tenth day. The skin stitches were removed on the same day. The postoperative and conservative management

The owners were advised to control the puppy’s activities, to keep it in an enclosed environment for the next two months, to exercise it regularly on the leash and to avoid stressing the joints with games, jumping, running and being left free in open spaces. We further advised regular swimming where possible in order to increase the puppy’s muscular mass. The same advice was given for those puppies that were treated conservatively.

Objective assessments

Two follow-up rechecks were scheduled, the first intermediate one after two to three months and the second, final one on completion of skeletal development at a minimum age of 12 to 18 months depending on breed. The minimum age for the official examination for CHD in the countries that have adopted the FCI system is 12 months for all breeds except for the giant breeds (Newfoundland, Mastiff, Dogue de Bordeaux, etc.) which require a minimum age of 18 months. At the end of the study the dogs in group 1 (treatment with JPS), group 2 (conservative treatment) and group 3 (negative controls) underwent a final evaluation of hip joint development on the basis of the Grade of CHD according to the FCI classification in 5 Grades (A, B, C, D, E) as shown in Table 3. The final classification was performed by the official CHD Italian panel of FSA (Fondazione Salute Animale), recognised by the Italian Kennel Club, in order to avoid any bias with the authors. Since one of the authors (AV) is a member of that panel, he was not involved in the final classification. The evaluation of dysplastic evolution considered only the dogs that had completed the study or that, due to severe progression of the pathology, required other surgical operations prior to the final recheck. In these cases the maximum Grade of CHD was attributed (E). In the FCI classification, the dogs with Grade A and Grade B hips are considered non-dysplastic, whilst dogs with Grade C hips are considered mildly affected, and dogs with Grade D and Grade E hips are considered to be clearly dysplastic. The efficacy of JPS to cause bony fusion of the pubic symphysis was evaluated radiographically at the final recheck.

**Further surgical procedures**

Two to three months later, when follow-up revealed that there was a significative progression of CHD, other surgical procedures were recommended (TPO, Darthroplasty, total hip replacement [THR], femoral head ostectomy [FHO]) without waiting for final evaluation on reaching skeletal maturity. These patients were then attributed Grade E at the final evaluation.

**Statistical analysis**

In this study, the outcome variable (grade of dysplasia) was a categorical variable that
was recorded on an ordinal scale with five levels. The predictor variables were:

- Severity degree at enrollment in the study: ordinal variable with three levels;
- Treatment: dichotomic variable JPS versus conservative treatment;
- Age at first diagnosis as a continuous variable.

In order to study the association between predictor and outcome variables, a proportional-odds model was fitted according to Venable & Ripley (32) and Dohoo et al. (33). The ordinality assumption for the outcome variable with respect to predictors was assessed by graphical method described by Harrel (34).

The models were used in order to estimate the probable grade of hip dysplasia, for each dog, according to Dohoo (33), in our dataset. More details to calculate the probabilities are reported in Appendix 1 of this paper. All statistical analyses were performed using R, a statistical software for data analysis and graphics (35) (Free Software Foundation's GNU General Public License).

### Results

Table 4 shows the distribution of all of the dogs from the three groups (JPS treatment, conservative management and negative control) inside the five FCI Grades of CHD at skeletal maturity, their final recheck. In Fig. 6, the five Grades of CHD are described showing examples of dogs treated with JPS.

Table 5 shows the resulting correlation between the severity of early signs of susceptibility to CHD (3 degrees of severity) and the evolution of the pathology observed at the end of the study (5 grades of CHD).

![Figure 8](image1.png) **Fig. 8** CHD grade A: Labrador Retriever, F., 18 months old; JPS was performed at 15 weeks of age. The dog was included in the intermediate-severity sub-group (β) when enrolled.

![Figure 9](image2.png) **Fig. 9** CHD grade B: Golden Retriever, F., 14 months old; JPS was performed at 16 weeks of age. The dog was included in the minor-severity sub-group (α) when enrolled.

![Figure 10](image3.png) **Fig. 10** CHD grade C: Golden Retriever, M., 12 months old; JPS was performed at 18 weeks of age. The dog was included in the intermediate-severity sub-group (β) when enrolled.

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Table 4  Distribution of all dogs of the three groups inside the 5 CHD grades according to FCI, at their final evaluation.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>17 (21%)</td>
<td>18 (22.2%)</td>
<td>21 (25.9%)</td>
<td>14 (17.3%)</td>
<td>11 (13.6%)</td>
<td>81</td>
</tr>
<tr>
<td>Group 2</td>
<td>2 (2.6%)</td>
<td>16 (21%)</td>
<td>16 (21.1%)</td>
<td>23 (30.3)</td>
<td>19 (25%)</td>
<td>76</td>
</tr>
<tr>
<td>Group 3</td>
<td>31 (52%)</td>
<td>23 (38%)</td>
<td>5 (8%)</td>
<td>1 (2%)</td>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

Table 5  Correlation between the severity of early signs of susceptibility to CHD (3 degrees of severity) and the evolution of the pathology observed at the end of the study (5 grades of CHD).

<table>
<thead>
<tr>
<th>Degree of severity of early signs</th>
<th>Treatment</th>
<th>CHD final grade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>α minor</td>
<td>JPS</td>
<td>14 (56%)</td>
</tr>
<tr>
<td>conservative</td>
<td>2 (7.7%)</td>
<td>14 (53.8%)</td>
</tr>
<tr>
<td>β intermediate</td>
<td>JPS</td>
<td>3 (10.7%)</td>
</tr>
<tr>
<td>conservative</td>
<td>0</td>
<td>2 (7%)</td>
</tr>
<tr>
<td>γ major</td>
<td>JPS</td>
<td>0</td>
</tr>
<tr>
<td>conservative</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>total</td>
<td>19</td>
<td>34</td>
</tr>
</tbody>
</table>
symphysis was evident in all of the cases. In 12 out of 81 cases few irregular spots of radiolucency were still present inside of the bony bridge.

**Statistical analysis**

The results of the fitted proportional odds model are reported in Table 6. In a proportional odds model, the estimated regression coefficients are measures of the effect of the involved predictor on the log odds of being above a specified level in comparison with the log odds of being below it. The exponentiation of the coefficients provides the odds ratio associated with the respective predictors. This OR is a measure of how increases in the odds of being in a category compared with being below. Hence, since CHD grades are ordered from the best to the worst category (A to E) the model tells us that the conservative treatment (OR\text{treatment}=\exp(1.934)=6.92) compared to the JPS increases the odds of being in a worse CHD category compared to the odds of being in the better one. In other words, adjusting for severity degree and age, the JPS increases the odds of being in a better category compared to the odds of being in the worse one. Since an odds is the ratio between a probability and the complement to one of the same probability (p/(1-p)), it is proportional to probability and comparing two odds provides a measure of two probabilities. Therefore, in clinical practice the regression coefficients estimated by the model could be used in the provided formulas (Appendix 1, formulas 1 and 2) together with the recorded values of the predictors age and severity grade to get the probability of being in the different classes according to the treatment group adjusting for age and severity grade. However, the model should be validated with external data before its routine clinical use, especially taking into account that the R^2 value was just 0.64.

**Complications**

There were not any complications during the surgical procedures and the owners reported complete recovery of the puppies within 24 hours of discharge from the hospital. Only one puppy had ulcerative lesions on the skin of its back in the post-operative period due to an electrical conduction defect in the neutral plate of the electrosurgical unit. A standard electrosurgical knife had been used in this case, with a neutral plate in contact with the patient. This complication never occurred when the radio frequency electrosurgical knife was used since the neutral plate was not in contact with the patient.

**Further surgical procedures**

In group 1, nine puppies underwent further corrective surgical procedures after the first postoperative recheck because JPS was not able to arrest the dysplastic process. Two patients underwent a bilateral TPO, three a bilateral darthroplasty operation, two puppies had a THR on the left side and darthroplasty on the right, while one required a THR in both joints, and one had a THR on the left side and TPO on the right.

In group 2, 14 puppies underwent other surgical procedures after the first recheck. Of these, five underwent bilateral TPO, four bilateral darthroplasty, and five bilateral THR.

**Discussion**

In our study, the electrocauterization of growth cartilage of the pubic symphysis in puppies aged 14–22 weeks that had been affected by initial CHD, arrested endochondral growth of the pubic symphysis (pubic symphysiodesis) and morphostructural
modifications of the pelvic girdle, and, in particular, of the acetabular roof. In a significant number of cases this resulted in involution, or at least, arrest of the dysplastic pathogenesis. This is in agreement with data found in the literature (12–16). We also found an improvement in the condition of the hips which is in line with publications on the positive effects obtained by acetabular ventral rotation, albeit achieved by TPO or JPS.

The extremely encouraging data on this new treatment had led us to inquire into its efficacy when the latter is evaluated in a clinical context, with all of the variables involved. The selection of the patients that were admitted to the study in fact reflects the diversified situations encountered in the clinical field, with different breeds, ages, grades of susceptibility to CHD and different owners with their various environmental conditions. If from a strictly speculative viewpoint these diversified situations constitute a defect in a standardised study, from a clinical reproducibility viewpoint they represent a positive aspect, reflecting an environmental influence and greater adherence to the daily practice situation. By examining a wide range of surveys we were able to evaluate the efficacy of the technique in different evolutionary stages of dysplastic pathology (3 degrees of severity in relation to the parameters evaluated in early diagnosis). Moreover, evaluating puppies subject to different environmental conditions, though grossly unified by the same advice on puppy management, we could see that the environment might, to a certain extent, influence the outcome of the treatment. In fact, puppies that had the same initial degree of severity subsequently developed different Grades of CHD, though in different percentages.

The results obtained from this study have highlighted an important aspect for a good surgical result: the correct evaluation of the puppy’s joint in order to carry out specific and careful patient selection. For the correct selection of a patient to undergo JPS, a preliminary and attentive study of the coxofemoral joint is necessary. It should be carried out early at the age of 14–22 weeks and include an orthopaedic examination with palpation of the hips (22) and an accurate radiographic screening with measurement of several parameters (3, 4, 16, 23).

Our study suggested that the early evaluation of the hip joints should not only be based on the standard ventral-dorsal view but must also take in other views (distraction and DAR) and palpation of the hips with evaluation of Ortolani sign and AR and AS. Owing to the fact that the standard ventral-dorsal view does not permit an in-depth evaluation of joint laxity and the form of the DAR, it can not provide an early evaluation that is reliable and capable of identifying patients for which JPS is indicated with a good prognosis. Moreover it was helpful not to rely on only a single parameter, although a significant one, but to carry out a comparison of the data obtained because the latter are closely correlated. Incongruity in the data gathered means either an error of measurement or erroneous interpretation of data. Comparison with other data therefore leads to a more reliable evaluation in our opinion. The DAR angle in younger puppies could be misleading due to the cartilaginous component that tends to overestimate the slope. In these cases the integrity or the erosion of the lateral border of DAR are more useful findings.

The study has demonstrated how age alone, whilst important, is not the sole decisive factor for a positive outcome of the operation. The prognosis is in fact highly influenced by the severity of susceptibility signs to CHD present at the first orthopaedic examination. In any case, it is necessary that there is still a good margin of skeletal growth in order to permit suitable rotation of the acetabula (13–16). Also, in the wake of experiments carried out in previous studies (3, 16), we have identified this limit as 22 weeks inasmuch as the best results were associated with an age equal to or less than 16 weeks. Twenty-two weeks is considered the limit age for giant breeds in which skeletal development is completed later, while for other breeds we have verified that 18 weeks is the upper limit for best exploitation of residual growth potential. This surgical procedure is carried out as early as possible regard exploitation of residual growth for a longer period, thus permitting greater rotation of the pelvis, and intervention before a potentially irreversible tendency to subluxation of the femoral heads is generated.

At the end of the follow-up rechecks, the dogs were subdivided into the five CHD grades defined by the FCI, in order to quantify evolution of the pathology in each individual patient. Patients in Grades A and B had normal or near normal hips that showed involution of the dysplastic pathogenesis; Grade C patients had mild CHD in which the disease was arrested and did not progress to severe OA, while Grades D and E comprised patients in which the coxofemoral joints showed severe deterioration and therefore a clear evolution of the pathology. A comparison of the distribution frequencies of the dogs that belonged to the two study groups within the final CHD Grades clearly showed that most of the group 1 patients (treated with JPS) can be found in the first three CHD Grades, whereas most of the conservatively treated puppies (group 2) are found in Grades D and E. In our clinical experiment, JPS carried out at an early age was a surgical technique which in 69.1% of cases led to involution of the dysplastic pathogenesis (Grades A, B), or to a limited evolution (Grade C). Hence, with the dogs included in this percentage, JPS obtained a positive result albeit to a different extent. In the remaining 30.9% of cases, there was a significant progression of OA, therefore with a negative result (Grades D and E). In group 2, only two dogs (2.6%) came under Grade A, and 21% under Grade B. Twenty-one percent of the patients showed light CHD (Grade C), while most of them, 55.3%, showed moderate and severe CHD (Grades D and E). This difference between the two study groups indicates that the joints of puppies undergoing JPS develop biomechanical conditions favourable to achievement of better joint congruity. The likelihood of developing severe CHD was almost double in the dogs that were treated conservatively versus the dogs treated with JPS.

We furthermore correlated the CHD Grades at adulthood with the parameters obtained from puppies at their first orthopaedic examination when enrolled in the study to check how the severity of initial signs of susceptibility to CHD influences the prognosis for JPS (Table 5). Fifty-six percent of the puppies belonging to the degree α, with in-
itial CHD signs of minor severity that had undergone JPS (group 1) showed normal joints (Grade A) on completion of skeletal development, and 32% developed near normal joints (Grade B), thus obtaining an excellent, or good, improvement in the dysplastic condition in 88%. Thereafter, in patients with these values the prognosis appears positive since JPS brings about a complete involution of the disease in most cases. In group 2, using the same parameters as at the first orthopaedic examination (degree \( \alpha \)), 7.7% developed normal joints (Grade A) and 53.8% near normal joints (Grade B), while 30.8% developed mild CHD (Grade C), and 7.6% underwent deterioration of the dysplastic form (Grade D and E).

The puppies belonging to degree \( \beta \), with initial CHD signs of intermediate severity, if managed in the conservative manner (group 2), only in the 7% showed no progression of their disease (Grade B), while in 64.4% of the cases there was a significant worsening of the dysplastic condition (Grades D and E). The results reveal that in the dogs with the same parameters and that are treated with JPS (group 1), there was involution of the dysplastic form (Grade A and B) in 46.4%. There was a limited progression of CHD (Grade C) in 35.7% of the cases, while only 14.3% of the cases showed moderate deterioration (Grade D), and 3.6% showed severe deterioration (Grade E). For these dogs the prognosis seemed good to fair, also in function of the age at which JPS was carried out. In the patients of this degree the timing of the surgical treatment was particularly crucial, with the possibility of fully exploiting residual growth as well as rigorously observing behavioural recommendations in order to avoid joint stress and to favour a better muscular tone.

The puppies that belonged to degree \( \gamma \), with initial CHD signs of greater severity and that were managed in a conservative manner, all showed a serious worsening of hips condition (Grade D and E). The results show that patients with the same initial parameters, if they underwent JPS treatment, in 28.6% of the cases there was a limited progression of CHD (Grade C of CHD); in 35.7% of the cases there was moderate deterioration (Grade D) and in 35.7% of the cases there was severe deterioration (Grade E). In puppies with these preoperative parameters the prognosis therefore did not appear to be as favourable as in the other two degrees. Also, in the puppies coming under this degree, the prognosis was, to a certain extent, improved by early intervention and by optimisation of the environmental conditions. What emerged, however, was the need to inform the owner in advance about the possibility that with these patients JPS might be ineffective and that the puppy might need further treatments.

In all three sub-groups, the study revealed that by keeping the same variables of severity of susceptibility signs to CHD as well as age, the results for those dogs that were treated with JPS and those that were managed conservatively showed an improvement of hips condition in all of the dogs treated with JPS of at least one CHD Grade. While one CHD Grade less is always a positive result, from a clinical perspective, a Grade D instead of a Grade E is not as significant as a Grade A or B instead of a Grade C, or of even more severe Grades. Moreover, the variability in the final result among dogs treated in the same way was strictly correlated to the severity of early signs of susceptibility to CHD. With the same treatment, increased odds to get a worse final CHD Grade compared to the odds of getting a better final CHD Grade were seen in dogs that belonged to more severe sub-groups.

When early diagnosis did not show any signs of susceptibility to CHD (group 3) there was not an indication for subjecting the puppy to JPS because 90% of these patients came under Grades A (normal) and B (near normal), 8% under Grade C (slight CHD), and only 2% developed more significant forms of CHD (Grades D and E). It therefore emerged that if the puppy has normal joints at early age it will not develop significant CHD as an adult, when a proper environment is provided. It therefore does not seem justified to carry out JPS indiscriminately as a preventive therapy for puppies of the breeds that are most subject to CHD without first checking for effective presence of susceptibility signs to this disease.

Certain environmental factors, such as feeding and exercise, can play a crucial role in the prognosis: hyper-nutrition and excessive, uncontrolled physical exercise lead to a worsening of the pathology before JPS can have a beneficial effect on joint biomechanics. A variation of environmental conditions, which is inevitable in clinical field conditions, could therefore explain the variability of results observed within the same degrees of severity of initial conditions. Breed variations could have played a role too, since a different response to hip joint laxity has been described in different breeds (27).

In our study, we did not observe any complications linked to the surgical operation. Iatrogenic damage to the abdominal organs,
especially to the urethra and rectum, has been described as a possible complication, hence it must be carefully avoided by protecting the abdominal organs with a gloved finger, or with a spatula in non-conducting material inserted dorsally to the pubic symphysis. The same electrocautery methods were used for each patient treated in this study. Therefore, even in the cases with a negative outcome, the lack of success cannot be attributed to an unsuitable surgical technique, although this possibility exists where the electrocautery technique is inadequate. To confirm the efficacy of JPS procedure, at the final recheck the pubic symphysis was evaluated for full bony fusion in its cranial part, shortening of the pubis rami, widening of obturator foramina and medial protrusion of acetabular fossa (Fig. 13). The bony fusion of the pubic symphysis at the final evaluation was the rule and the small radiolucent spots inside the ossified pubis observed in 12 cases did not affect the bridging effect of the bony fusion; they could be related to residual fibrous tissue inside the ossified pubis. Due to the prolonged electrocautery actions, skin burns under the neutral plate are possible. This complication can be avoided by improving conduction of the neutral plate with conductive gel or by using radio frequency electrosurgical units which do not need plate contact with the patient.

Conclusions

In our clinical study, while JPS always resulted in a better outcome than the conservative management, it was clinically most effective for arresting or limiting the development of CHD mainly in puppies that were admitted with slight or moderate signs of susceptibility to CHD during their clinical and radiographic examination at the age of 14–22 weeks. JPS had little to no clinical efficacy in puppies with more severe initial signs of CHD and moreover was not indicated for puppies who did not show any signs of susceptibility to CHD. Therefore, JPS appeared to be a surgical procedure capable of reversing or arresting the evolution of CHD in selected cases. In the selection of good candidates for JPS a very early evaluation of at-risk breed puppies is necessary: between the 14th and 16th week for medium-large breeds and between the 18th and 20th week for giant breeds. Table 7 shows the results which might be expected from the JPS surgical procedure in puppies aged 14–22 weeks, drawn up on the basis of the preliminary physical and radiographic evaluation and of the results in terms of efficacy obtained in this study. An ‘excellent’ prognosis means a regression of the pathology with normalization of joint development. A ‘good’ to ‘fair’ prognosis means the arrest of the dysplastic process, not regression, but the avoidance of severe progression. Patients given a ‘poor’ to ‘unfavourable’ prognosis are unlikely to fully benefit from this surgical procedure. Therefore, JPS should not be carried out indiscriminately in all puppies subject to early diagnosis. Neither cases with an over advanced form of CHD nor those with normal coxofemoral joints will benefit from this kind of treatment. Proper and attentive handling of the puppy in the postoperative period also plays an important role in the success of JPS. From the ethical point of view, since JPS is significantly efficacious only in the mild to moderate forms of CHD, and since these Grades of CHD are usually tolerated by the dog, it may be argued that this operation is unnecessary. However, we believe that whilst a dog can well tolerate mild or moderate CHD, it would certainly enjoy greater functionality and well-being with a normal or near normal joint condition, and also meet its owner’s expectations of an active life without limitations. Preventive treatment of mild and moderate forms of CHD with JPS seems further justified by the fact that these Grades of CHD in particularly active and heavy dogs may easily evolve with aging into more severe forms, with a progression of coxarthrosis such as to bring about a diminution of functionality, chronic pain and the need for more invasive surgery later in their life. JPS is a surgical procedure that modifies the phenotype of the dog, and, unlike other techniques, such as TPO, acetabuloplasty or THR, it does not always leave obvious radiographic signs of its execution, even if careful evaluation of the pubis modifications and the pelvis shape could reveal signs of suspicion. This fact carries an important ethical implication: those puppies that were successfully treated with JPS, may as adults appear absolutely normal when officially tested for CHD and could therefore be used for reproductive purposes, through ignorance or bad faith, in spite of their affected genotype. Moreover, females treated with JPS may undergo such narrowing of the pelvic girdle as to impede natural birth (13). These aspects must be discussed in depth with the puppies’ owners in order to make them aware of this problem and to obtain fully informed consent regarding contraindication for future use of these patients for breeding purposes.

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References

Appendix

Computation of the probabilities of being in different dysplastic classes

A proportional-odds model assumes that the ordinal outcome variable represents categories of an unobserved continuous latent variable (LV). According to the assumption that this latent variable is a linear combination of the predictor variables, it can be calculated for each individual with the following formula:

$$LV_i = b_1 X_{1i} + b_2 X_{2i} + \ldots + b_k X_{ki} + e_i$$

where b’s are the regression coefficients estimated by the model, X’s are the predictors and e_i is a random error term from a continuous distribution. The LV is divided by cut-points (C) so that the ith individual is classified as category 1 (first category) if $LV_i \leq C_1$ and is classified as category 2 if $C_1 < LV_i \leq C_2$, and so on.

Then the probability of observing outcome j in the ith individual, assuming a logistic distribution for random error term(εi) is:

$$P(LV_i < C_j) = 1/1 + e^{LV_i - C_j}$$

Example:

For a male Setter we have recorded treatment group = 0 (JPS), severity grade = 1 and age = 16.

The comparison minor category for categorical variables will be coded as 0 while the observed category will be coded as 1.

Since the estimated regression coefficient (β) for age is 0.1179, then the latent variable LV for this dog will be:

$$LV_i = 1.9340 * 0 + 2.6080 * 0 + 0.1179 * 16 = 1.8864$$

We have four cut-off values for the five grades of dysplasia computed by the model:

- Cut-off 1 = 2.0028
- Cut-off 2 = 4.2485
- Cut-off 3 = 6.2680
- Cut-off 4 = 8.3643

We can calculate the probability for this dog of being in the first category (A):

$$P(LV_i \leq \text{Cut off 1}) = 1/1 + e^{1.8864 - 2.0028} = 0.53 \text{ (53%)}$$

To calculate the probability of being in the second category (class B) we have to first calculate the cumulative probability to fall in first or second category:

$$P(LV_i \leq \text{Cut off 2}) = 1/1 + e^{1.8864 - 4.2485} = 0.914 \text{ (91%)}$$

Then subtracting from this cumulative probability (91%) the probability of being in the first category (53%) we get the probability to fall exactly in the second category (class B): 91% - 53% = 38%.

The same computation procedure will be applied to calculate the probability of being in the other classes. The sum of all the computed probabilities will be 1 (100%).

A | B | C | D | E
---|---|---|---|---
1 | 2 | 3 | 4 | 5


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