Prophylactic Pinning of the Contralateral Hip in Slipped Capital Femoral Epiphysis

Evaluation of Long-Term Outcome for the Contralateral Hip with Use of Decision Analysis

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Background: The risk of a contralateral slip in patients who are first seen with a unilateral slipped capital femoral epiphysis has been reported to be 2335 times higher than the risk of an initial slip. The overall prevalence of bilaterality varies widely throughout the literature, with some reports indicating rates as high as 80%. This finding has led many authors to recommend prophylactic pinning of the contralateral asymptomatic hip in patients presenting with a unilateral slipped capital femoral epiphysis.

Methods: A decision analysis model with probabilities for the occurrence of contralateral slip and for the severity of slip at different intervals of follow-up was used in the present study. These probabilities were compared with those for various outcomes when the contralateral hip is prophylactically pinned. Scores representing long-term outcome, according to the Iowa hip-rating system, were used in the model as a measure of utility. The probabilities of contralateral slip and the rates of slip severity were taken from large retrospective series. All meaningful clinical scenarios with regard to long-term outcome for the hip were considered in the model. Variables of uncertainty were subjected to sensitivity analyses in order to explore the effect on outcome over the range of plausible values for variables of interest.

Results: The results showed a benefit in the long-term outcome for patients who had prophylactic pinning of the contralateral hip. The threshold level at which a benefit is obtained with prophylactic pinning is expressed according to the rates of sequential slip, rates of slips overlooked at follow-up, and complications associated with prophylactic pinning of the contralateral hip.

Conclusions: The decision model shows that, when pooled data are used to predict probabilities of sequential slip, treatment of the contralateral hip with prophylactic pinning is beneficial to the long-term outcome for that hip. When considering prophylactic pinning of the contralateral hip, the clinician should use sound clinical judgment with respect to the age, sex, and endocrine status of the patient. Long-term follow-up studies are needed to establish the efficacy of prophylactic pinning, but the predictions in the present study, which are based on findings in the literature, support the safety of this procedure.

Patients who are first seen with unilateral slipped capital femoral epiphysis are at a 2335-times greater risk for the development of a contralateral slip than are those who have never had a slip[1]. This increased risk and the noted association between slipped capital femoral epiphysis and the development of osteoarthritis[2-11] has led some authors to recommend prophylactic pinning of the contralateral hip, even when the patient has an asymptomatic, radiographically normal contralateral hip[7,9,12-14]. Proponents of prophylactic pinning have argued that slipped capital femoral epiphysis is a disease of the physes[15], which places the patient at substantial risk for slip until physeal closure occurs, and they have advocated treatment of the contralateral hip prior to progression to slip.

Many authors, however, have concluded that close follow-

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up of the contralateral hip is sufficient or that prophylactic pinning should be performed only in select patients with endocrinopathies, renal failure, or a young age at presentation or in those who may be unreliable about returning for follow-up[1,11,16-21]. Those favoring observation argue that the major risks of the procedure, chondrolysis and avascular necrosis[22], outweigh the potential benefits. They also believe that the majority of sequential slips are detected before they progress to more severe slips, allowing for good outcome with treatment. Other concerns that relate to prophylactic fixation include the potential for infection, hardware breakage, irritation associated with the hardware, difficult extraction of the hardware, fracture, and unnecessary operations on hips that would not have gone on to slip.

Surgical options are aptly suited for decision analysis as they frequently involve concrete treatment options (surgery or no surgery) and relatively discrete outcomes[23]. While this tool has been used in the business world for many years, it has been used only recently in the analysis of health outcomes. A number of well-written papers have been published to assist the reader in understanding the process and applicability of decision analysis modeling[24-33]. While many think that decision analysis provides an overstructured, unrealistic model of real clinical decision-making, it nonetheless provides a powerful estimation of outcome based on established clinical data and individual patient utilities or preferences, which the clinician may not intuitively recognize.

The basics of medical decision analysis involve a clinical scenario with at least two options for treatment followed by a series of potential clinical outcomes with their associated probabilities. The method is rooted in the Bayesian theory of probability. The process first involves the construction of a decision tree, which should represent all relevant clinical outcomes associated with each treatment option. The tree begins with the root node (represented by a square) from which the options for treatment are displayed as branches. The probabilities for each clinical outcome are then determined on the basis of evidence in the medical literature or as best estimates from authorities in the particular field of study. These probabilities are displayed as chance nodes (represented by circles) each time an event of uncertainty occurs. Each chance node eventually ends in a terminal node (represented by a triangle), which represents a discrete clinical outcome. Clinical outcomes are assigned a value (utility) in the form of a linear scale, which reflects either patient preferences or some objective measure of outcome. In the medical literature, utilities are frequently expressed in quality-adjusted life-years.

The probabilities of attaining each clinical outcome are then multiplied in sequence by the utility associated with that particular outcome in a process known as “folding back the tree.” These values are then summed for each branch of the root node, and an expected value is obtained for each treatment option. The preferred clinical strategy can then be inferred from the branch of the root node that has the largest expected value. The stability of the model is then assessed with sensitivity analysis, which involves changing the values of uncertain variables over their plausible ranges and exploring the effects on the outcome of the model.

In the present study, we formulated a decision analysis model that was based on two options for the treatment of the contralateral hip in patients with unilateral slipped capital femoral epiphysis: prophylactic operative fixation (with a single cannulated screw) or observation with close clinical and radiographic follow-up. This model addressed skeletally immature individuals who were first seen with a unilateral slipped capital femoral epiphysis. The probabilities of various clinical outcomes were derived from reports in the literature and were used to predict the outcome for the contralateral hip on the basis of the method of treatment chosen. The probabilities were obtained from a large series reported in the litera-

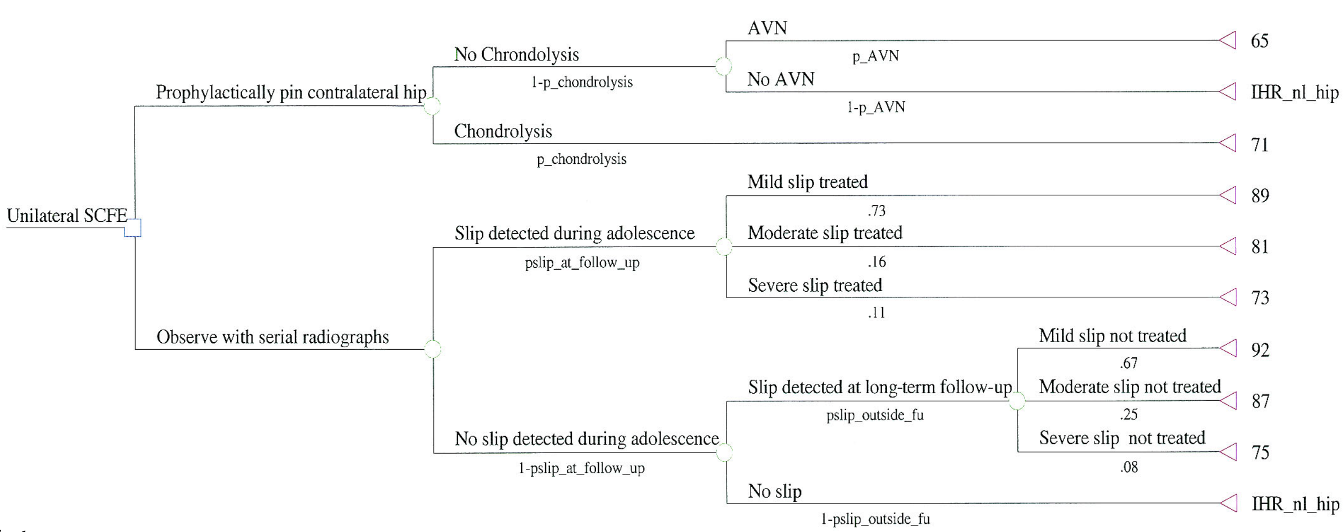

Fig. 1

The complete decision tree with probability and utility variables. SCFE = slipped capital femoral epiphysis, AVN = avascular necrosis, and IHR_nl_hip = normal hip.

ture in which the patients had a mean age of approximately 13.7 years at the time of the initial slip and girls had a mean age of approximately 11.9 years at the time of the index slip[1]. Utility was measured with use of the Iowa hip-rating scores from long-term follow-up studies of patients with slipped capital femoral epiphysis. All clinical outcomes with relevant impact on the long-term outcome for the hip were considered in the model. Sensitivity analyses were performed to assess the stability of the model for the probabilities and utilities of greatest uncertainty.

Materials and Methods

Decision Tree

The decision tree and sensitivity analyses were performed with use of Data 3.5 software (TreeAge Software, Williamstown, Massachusetts).

The decision tree demonstrates two options for the management of the contralateral hip in a clinical scenario in which the patient presents with a unilateral slipped capital femoral epiphysis and an asymptomatic, radiographically normal contralateral hip (Fig. 1). The root node (where the decision is made) divides into two arms: observation with serial radiographs and prophylactic pinning of the contralateral hip. Each branch of the decision node is then followed by a number of different chance nodes, each eventually terminating in discrete clinical outcomes.

Prophylactic Pinning Arm

The branch that refers to prophylactic pinning is subject to two meaningful complications, avascular necrosis and chondrolysis. Other complications associated with prophylactic pinning that have been reported in the literature are pin penetration, fracture, infection, pin breakage, growth disturbance, wound problems, subsequent slippage, and difficult pin extraction during hardware removal[13,14,34-48]. Pin penetration is a concern because of the risk of chondrolysis, but this event alone has not been shown to be sufficient for the development of chondrolysis[48,49]. A second operation may be required, but the effect on long-term outcome is likely to be minimal if chondrolysis does not ensue.

Fracture is a concern that is seen primarily after hardware removal[14]. It is unlikely that fracture, although a source of considerable short-term morbidity, would contribute substantially to deterioration of the long-term outcome for the hip as most fractures are extracapsular and are related to the stress-riser effect or to a cortical defect resulting from removal of the hardware[44]. Additionally, many pediatric orthopaedists debate the necessity for removal of hardware in asymptomatic hips. Several studies have documented the morbidity associated with hardware removal[35,44], and none found any complications that would have a meaningful effect on the long-term function of the hip.

Finally, infection is always a concern with any operative procedure. Rates that have been reported in the literature are extremely low and involve, almost exclusively, superficial infection. Intra-articular infection following in situ pinning has not been reported; therefore, the likelihood that such an infection would make a substantial contribution to the outcome variable is minimal and was not considered in the model.

Other concerns such as limb-length discrepancy, pre-

TABLE I Definitions of Variables in Decision Tree

Variable	Tree Definition	Baseline	Range	Studies
Rate of avascular necrosis (prophylactic pinning)	p_AVN	0.01	0-0.015 0-0.25*	Carney et al.[4], Hansson et al.[5], Emery et al.[13], Ghanem et al.[14], Aronson and Carlson[34], Greenough et al.[37], Kumm et al.[40], Nishiyama et al.[61], Kennedy et al.[62]
Rate of chondrolysis (prophylactic pinning)	p_chondrolysis	0.01	0-0.077 0-0.25*	Carney and Weinstein[3], Emery et al.[13], Ghanem et al.[14], Aronson and Carlson[34], Greenough et al.[37], Kumm et al.[40], Nishiyama et al.[61]
Slip detected during adolescence	pslip_at_follow_up	0.135	0.078-0.224	Carney et al.[4], Hägglund et al.[7], Wilson et al.[11], Jerre et al.[19], Loder et al.[21], Jensen et al.[54], Schreiber[63], Siegel et al.[64], Sorensen[65]
Slip detected in long-term follow-up†	pslip_outside_fu	0.507	0.252-0.507 0-0.507*	Hägglund et al.[7], Jerre et al.[19], Jensen et al.[54], Schreiber[63]

*Range used in the model (exceeds the range suggested by the literature). †Slips that went undetected or were not treated prior to skeletal maturity.

mature physeal arrest, and dislodgment of the fixation device by continued physeal growth were not included in the model because the prevalence and clinical impact of these factors on the long-term function of the hip are not important. These assumptions are supported by the findings of a recent study on the efficacy and safety of fixation with a single cannulated screw[47]. It also stands to reason that limb-length discrepancy would be related more to nonoperative treatment of the contralateral hip than to prophylactic pinning and may actually be a consideration that would favor the use of prophylactic pinning[45].

Serial Observation Arm

The serial observation branch follows the logical follow-up chronology. The first probability node refers to the probability that a contralateral slip will be detected during the follow-up period (pslip_at_follow_up). This occurrence is often reported in the literature as a slip detected "during adolescence." This branch then terminates in three potential outcomes—that is, mild slip treated, moderate slip treated, and severe slip treated. The method of treatment is not differentiated.

Patients who do not have a slip during adolescence or who have a slip that is unrecognized prior to skeletal maturity continue in the tree as survivors. The next probability node is the probability of a contralateral slip that is not detected until skeletal maturity. This value is derived from follow-up studies in the literature that have shown evidence of slip that was not previously recognized during the adolescent period. This branch then terminates in three potential outcomes—that is, mild slip not treated, moderate slip not treated, and severe slip not treated.

All other survivors are then recognized as never having had a sequential slip. This branch terminates with the outcome designated as a normal hip (IHR_nl_hip).

Probabilities

The probability variables were taken directly from the medical literature. Rates of avascular necrosis and chondrolysis were given a baseline value of 0.01 each as an arbitrary estimation of risk. Table I summarizes the reported rates of avascular necrosis and chondrolysis in the literature. No reports of avascular necrosis or chondrolysis following prophylactic pinning were identified in the literature. Reference ranges of 0 to 0.08 for chondrolysis and 0 to 0.02 for avascular necrosis were used in the model. Both upper limits were derived from the series of mild slips reported by Carney et al.[4]. Thus, it is reasonable to assume that the upper limit of the rates of avascular necrosis and chondrolysis associated with prophylactic pinning would fall somewhere in this range. Wider reference ranges of 0 to 0.25 were used for chondrolysis and avascular necrosis in the sensitivity analyses to establish threshold rates. Therefore, the rates of chondrolysis and avascular necrosis used in the present study are higher than those suggested by the available literature.

Baseline values for the probability of contralateral slip were obtained from Hägglund et al., who reported what we believe is the largest series of patients with slipped capital femoral epiphysis in the literature[7]. Of the 260 patients in that study, twenty-three had a bilateral slip at the time of admission; therefore, they were excluded from the calculation, leaving a total of 237 patients. Thirty-two patients had a contralateral slip during adolescence. Thus, the rate of sequential slip detected at follow-up (pslip_at_follow_up) was 0.14 (32/237). At long-term follow-up (range, sixteen to sixty-six years; average, thiry-three years), 104 additional patients were noted to have sequential slip that had not been identified when they were adolescents. Thus, the probability of a slip that was not detected at follow-up (pslip_outside_fu) was 0.51 (104/205). Determination of these slips was performed with use of the radiographic technique of Billing and Severin[50]. The degree of anteversion was measured, and a lateral view was performed in this plane. The calcar femorale is parallel to the femoral neck and can be used as a radiographic landmark from which the normal position of the center of the femoral head can be predicted. If the displacement of the femoral head is greater than three standard deviations below its predicted position, it is regarded as a slip. Similar calculations were performed with data from other large series that had follow-up information available. These studies provided the reference ranges for the variables described above (Table II).

The probabilities of slip severity were reported by Castro et al. in a meta-analysis of several large retrospective series[1]. The pooled results of slip severity for 328 hips included 239 hips (73%) with a mild slip, fifty-four (16%) with a moderate slip, and thirty-five (11%) with a severe slip. Slip severity was not defined in that study. Thus, the probability values detected at follow-up were 0.73 for mild slip, 0.16 for moderate slip, and 0.11 for severe slip.

In the study by Hägglund et al., 104 patients had a sequential slip that was not identified until adulthood (i.e., it was missed during adolescence); seventy of them had a mild slip, twenty-six had a moderate slip, and eight had a severe slip[7]. The slip severity was classified according to the system of Bianco, with a mild slip defined as displacement of less than one-third of the diameter of the femoral head; a moderate slip, as displacement of one-third to two-thirds of the diameter of the femoral head; and a severe slip, as displacement of more than two-thirds of the diameter of the femoral head[51]. The probability of the severity of a slip not detected during adolescence was 0.67 (70/104) for a mild slip, 0.25 (26/104) for a moderate slip, and 0.08 (8/104) for a severe slip.

Utilities

Outcome was assessed with use of standard health-status evaluations rather than patient preferences. While somewhat unconventional in decision analysis, this method represents the most objective measure of outcome for the hip while maintaining the properties of a linear scale required in utility analysis[23,33].

The most comprehensive long-term follow-up data, to our knowledge, on slipped capital femoral epiphyses were reported by Carney et al.[3,4], who used the Iowa hip-rating

TABLE II Data for Calculation of the Probabilities of Slip Used in Model

Study	No. of Patients			Slip Detected at Follow-up		No. of Survivors Through Adolescence	Slip Detected at Long-Term Follow-up*	
	Total	Bilateral Slip at Admission	Unilateral Slip at Admission	No. of Patients	Probability (pslip_at_ follow_up)		No. of Patients	Probability (pslip_ outside_fu)
Jerre et al.[19]	153	24	129	10	0.078	119	30	0.252
Schreiber[63]	100	27	73	6	0.082	67	32	0.478
Wilson et al.[11]	240	29	211	31	0.147	180		
Sorensen[65]	101	13	88	12	0.136	76		
Hägglund et al.[7,9]	260	23	237	32	0.135	205	104	0.507
Jensen et al.[54]	62	5	57	9	0.158	48	16	0.333
Siegel et al.[64]	45	11	34	7	0.206	27		
Carney et al.[4]	124	14	110	17	0.155	93		
Loder et al.[21]	224	41	183	41	0.224	142		

*No value is given for studies that did not include the rate of slip noted only at long-term follow-up (i.e., slips recognized after skeletal maturity, which were not surgically treated).

system[52] to determine the outcome after long-term follow-up. As the Iowa hip-rating system is a relatively objective linear measure of functional level and pain, it provides a relevant valuation of outcome that can be utilized in a decision tree to assess linear quantitative benefit.

According to the Iowa hip-rating system, 90 to 100 points is an excellent result; 80 to 89 points, a good result; 70 to 79 points, a fair result; and <70 points, a poor result. The baseline value for a "normal hip" was 100 points, but the reference range was extended from 92 to 100 points, as 92 is the score associated with mild, untreated slips. This range is necessary to account for the possibility of an unknown abnormality of the hip in patients with slipped capital femoral epiphysis that leads to a poorer outcome regardless of the presence of slip. Additionally, this range accounts for the possibility that the patient may have arthritis or other abnormalities of the hip that are not a direct result of a slipped capital femoral epiphysis.

At a mean duration of follow-up of forty-one years, mild slips (treated by different methods) had a mean Iowa hip-rating score of 89 points, moderate slips had a mean score of 81 points, and severe slips had a mean score of 73 points[4]. Slip severity was classified according to the difference in the head-shaft angle between the two sides as seen on the anteroposterior radiograph. The slip was considered mild if the difference was <30°, moderate if the difference was between 30° and 50°, and severe if the difference was >50°.

The values for slips that were not detected at follow-up were taken from the study of the natural history of slipped capital femoral epiphysis by Carney and Weinstein[3]. They evaluated twenty-eight patients in whom a slip was diagnosed during adolescence but was not treated. The mean Iowa hip-rating scores were 92 points for mild slips, 87 points for moderate slips, and 75 points for severe slips.

The Iowa hip-rating scores for avascular necrosis and chondrolysis were taken from individual scores reported in the study by Carney et al.[4]. The mean score was 65 points for the hips that had avascular necrosis and 71 points for the hips that had chondrolysis.

Sensitivity Analyses

The inherent uncertainty of a decision model can be explored with a powerful tool known as sensitivity analysis. The variables of greatest uncertainty can be analyzed over their range of plausibility one at a time or in conjunction with other variables to explore the effects of the uncertainty on the results of the model. Sensitivity analysis is the equivalent of statistical testing in conventional data analysis. A threshold value in which the point of intersection, or "toss-up state," occurs with each variable can then be determined. The threshold represents the boundaries of the variables that indicate when one clinical strategy is more beneficial than another.

The variables of greatest uncertainty and debate in this study are the probabilities of avascular necrosis and chondrolysis in the prophylactically pinned hip and the likelihood of sequential slip.

The variable with the widest range of reported values in the literature is the rate of bilaterality. The rates reported in the literature have ranged from 10% to 80%, with rates in most studies in the range of 25% to 50%[1,4,11,21] when the patients were followed through adolescence. The range increased to between 40% and 80%[7,9,50,53,54] when the patients were reexamined in adulthood. The literature is relatively consistent with regard to reported ranges of sequential slip detected during adolescence (range, 7% to 25%); however, there is great

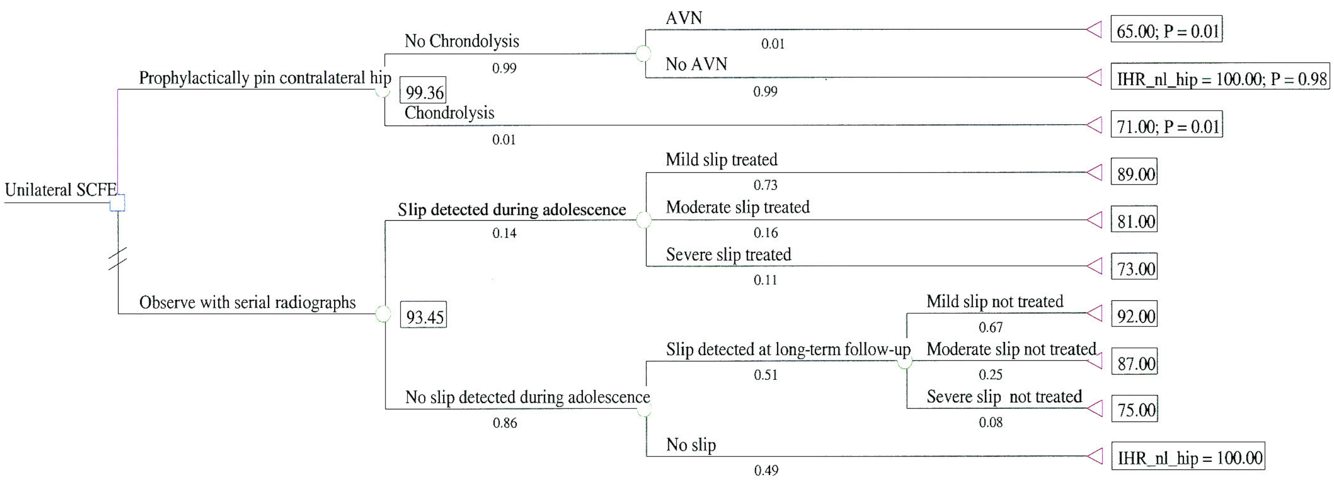

Fig. 2
The complete decision tree with baseline values and with results of the "fold-back" process. The expected value of prophylactic pinning is 99.36, and the expected value of radiographic observation is 93.45. SCFE = slipped capital femoral epiphysis, AVN = avascular necrosis, and IHR_nl_hip = normal hip.

disparity in the medical literature with regard to slips that were not detected until long-term follow-up (well beyond skeletal maturity). This disparity is largely due to the different radiographic criteria used throughout the literature. To explore this potential source of debate, the variable (pslip_outside_fu) was analyzed at a minimum value well below the lowest values reported in the literature (0%).

Sensitivity analysis was performed on all variables individually, and two-way sensitivity analysis was performed for multiple variable combinations to explore the effect on the decision model.

Results

The results of the decision model after the "fold-back" process was performed demonstrated a score of 99.4 for prophylactic pinning of the contralateral hip and a score of 93.5 for observation (Fig. 2). The initial analysis was performed with baseline rates for the variables shown in Table II.

One-way sensitivity analyses were performed for all variables (see Appendix). When analyzed independently, only two variables (p_AVN and p_chondrolysis) were found to change the results of the model within their plausible ranges. The threshold rate at which avascular necrosis turns the model in favor of observation occurs when the rate of avascular necrosis associated with prophylactic pinning is 18.1%. The threshold rate of chondrolysis occurs at 21.6%. The other variables (pslip_at_follow_up, pslip_outside_fu, and IHR_nl_hip) do not have meaningful impact on the model when varied in isolation; thus, they are considered "robust."

Two-way sensitivity analysis of the effect of varying the rates of chondrolysis and avascular necrosis associated with prophylactic pinning created a threshold value at which the rates of avascular necrosis and chondrolysis favored observation rather than prophylactic pinning (Fig. 3). If the rate of avascular necrosis were 1%, then the rate of chondrolysis would have to be as high as 22% for the model to favor observation. Similar threshold values can be calculated from the graph on the basis of varying rates of avascular necrosis and chondrolysis.

The effect of varying the frequency of sequential slip showed that, even when the level of follow-up of detected slips was very low, the probability of an undetected slip would have to be well below the values reported in the literature for the model to favor observation (Fig. 4).

Three-way sensitivity analyses on the most controversial variables (p_AVN, p_chrondrolysis, and pslip_outside_fu) demonstrated that the model would favor serial observation if the rate of slips not detected during adolescence remained at zero (i.e., all slips were detected prior to skeletal maturity) and the rate of avascular necrosis and chondrolysis with prophylactic pinning were each >5% (see Appendix [Figs. E-6 through E-11]).

Discussion

The results of this decision analysis model favor prophylactic pinning of the contralateral hip when model probabilities are held within the values defined by reports in the literature. It is important to recognize that this model describes only the long-term outcome for the hip as measured according to the Iowa hip-rating system. The model does not incorporate patient preferences and does not assess their relative willingness to assume or avoid risk. The model uses probability rates that have not been exclusive of specific patient populations; thus, it does not stratify risk according to patient demographics.

This model is perhaps most valuable as a predictor of outcome when observation is chosen. Long-term follow-up data on series of hips treated with prophylactic pinning are not available; thus, the model is an attempt to predict the long-term outcome for the contralateral hip on the basis of

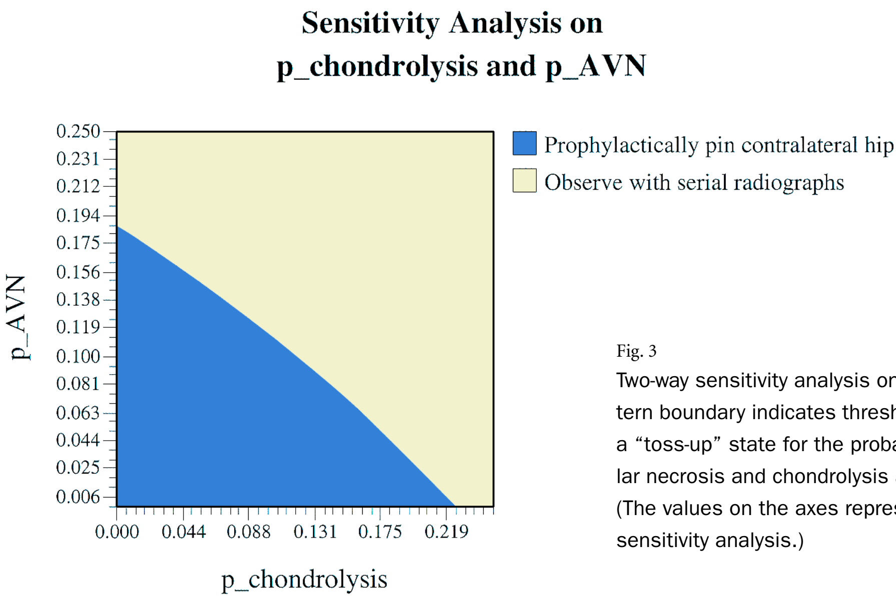

Fig. 3

Two-way sensitivity analysis on p_chondrolysis and p_AVN. The pattern boundary indicates threshold rates at which the model indicates a "toss-up" state for the probabilities for the development of avascular necrosis and chondrolysis associated with prophylactic pinning. (The values on the axes represent the ranges of the variables in the sensitivity analysis.)

the literature that is available. It is certainly plausible that the ability to detect slips radiographically has become better as imaging techniques have improved, and thus the rate of slips missed during adolescence may be considerably lower than that reported by Hägglund et al.[7].

Ideally, a decision model should use a patient-based scoring system, evaluating outcome on the basis of patient utilities. However, when functional levels and pain in the hip are evaluated, use of a patient-based scoring system becomes very difficult and subjective. For example, evaluating the relative preference of minimal versus moderate degenerative changes in the hip is very difficult for patients to understand in terms of the impact on the quality of life and functional level. It is in such circumstances that a uniform, relatively objective measure of outcome such as the Iowa hip-rating system provides an invaluable measure of utility, which may be difficult to assess with standard methods of utility calculation, such as the time trade-off or standard gamble. Nonetheless, patient preferences should be taken into consideration when this model is evaluated. A manual laborer may regard a small loss of function of the hip as a substantial impairment, whereas a more sedentary individual may not value this difference. These are issues that the Iowa hip-rating may not adequately assess.

It is still difficult, despite the results of the model, to overlook immediate perioperative issues such as infection, operative pain, potential for fracture, and additional operations that might otherwise have been unnecessary; however, when weighed against the devastating potential of life-long pain and disability from a diseased hip, it is clear that there is a tendency for surgeons to place too much weight on such short-term issues. Using the example of Legg-Calvé-Perthes disease,

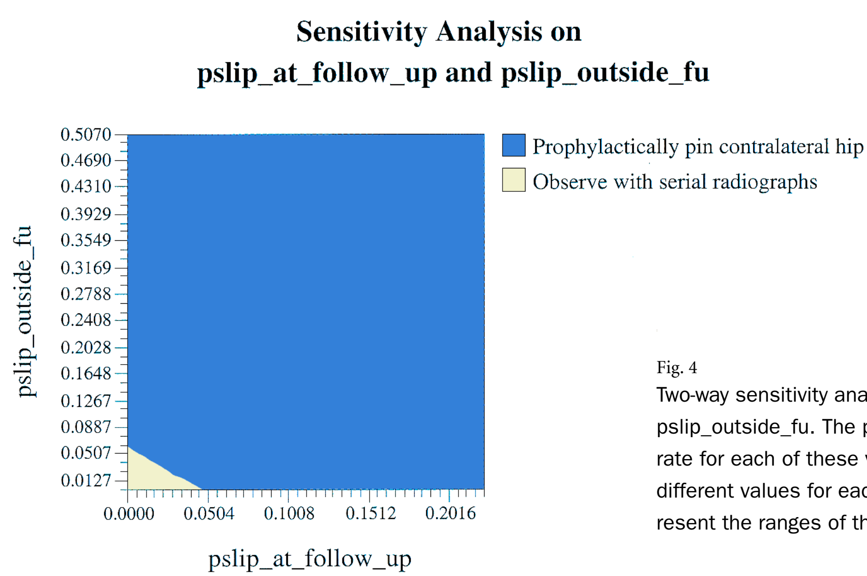

Fig. 4

Two-way sensitivity analysis on pslip_at_follow_up and pslip_outside_fu. The pattern boundary displays the threshold rate for each of these variables and the strategy preferred at different values for each variable. (The values on the axes represent the ranges of the variables in the sensitivity analysis.)

TABLE III Results in Three Retrospective Series of Hips Treated with Prophylactic Pinning

Study	No. of Hips	Type of Fixation	Avascular Necrosis	Chondrolysis	Other Complications
Emery et al.[13]	95	Multiple Crawford-Adams pins	0	0	Superficial wound infection (5 hips), prominent hardware (7 hips)
Ghanem et al.[14]	74	Single cannulated screw	0	0	Infections (none), fracture sustained in motor-vehicle accident (1 hip), late slip after hardware removal (2 hips)
Kumm et al.[40]	34	Dynamic single cannulated screw	0	0	Hypertrophic scars (2 hips)

many surgeons regularly perform varus osteotomies in the hope of improving containment of the diseased femoral head. The improvement in outcome associated with this procedure over the natural history of the disease has not been clearly established[55], but surgeons are less likely to feel hesitant to perform an operation when they perceive a problem to be present. It is this sense of "needing to do something for the patient" that may be somewhat irrational and counter to the medical evidence. The case of prophylactic pinning of the contralateral hip in a patient with slipped capital femoral epiphysis is the polar opposite of such a scenario. Perhaps the surgeon's reluctance is due to the perception that there is not a problem in the contralateral hip, and therefore it is unwarranted to take risks on the behalf of the patient. Thus, they are guided by the principle of "first do no harm."

The goal in the treatment of slipped capital femoral epiphysis is to prevent further slip. There is an associated probability of progression with each stage of slip (mild, moderate, and severe), and outcome studies have clearly documented poorer outcomes associated with progression of slip severity[3,4,56]. There is also a given probability of progression from no slip to a mild slip in the contralateral hip. If this probability were similar to that of progression of an existing slip, then the fundamental goals of treatment would suggest pinning. If the contralateral hip in a patient with slipped capital femoral epiphysis were thought of as "preslip," then, given the extraordinarily high rate of progression to mild slip, surgeons would perhaps be less apprehensive with regard to the need to prophylactically pin the contralateral hip.

Additional Issues Favoring Observation

Issues that were not addressed in the model but that are certainly worthy of consideration are the age, race, sex, weight, and endocrine status of the patient. Insufficient data are available in the literature to construct a valid model based on individual demographic differences. Although the precise risk reduction cannot be assessed, it is clear that the risk of contralateral slip is markedly lower as patients become more skeletally mature. Stasikelis et al.[57] showed that the modified Oxford method for the assessment of bone age was an accurate predictor of the probability of contralateral slip. Burrows, in a series of 100 cases, found no sequential slips in postmenarcheal girls[58]. Blacks, obese children, and children with endocrinopathies[18,21] are known to have a higher rate of contralateral slip, and these variables should certainly be taken into consideration. Clearly, as skeletal age increases, the risk of sequential slip diminishes. When this model is incorporated into clinical decision-making, it is paramount that clinicians recognize these shortcomings of the model. The individual risk factors for each patient should be taken into consideration with use of sound clinical judgment. As data evolve, this model will perhaps eventually be able to predict individual risk on the basis of the specific risk factors of the patient.

Before prophylactic pinning of the contralateral hip is recommended, an understanding of the risks of the procedure is paramount. Reports in the literature have verified the safety of this procedure in institutions where it is performed frequently[12-14,39] (Table III); however, the safety of the procedure in the hands of less experienced surgeons is not known.

In addition, studies in which the safety of prophylactic pinning has been examined have not shown the long-term outcome for these patients[13,14,40]. It is possible that some underlying abnormality in the hip predisposes the patients to increased rates of degenerative disease regardless of the presence of slip.

Additional Issues Favoring Prophylactic Pinning

A concern for any orthopaedist who chooses to observe the contralateral hip is the permitted activity level of the patient prior to skeletal maturity. Many orthopaedists recommend strict activity restrictions, which can be quite life altering to an adolescent. This line of reasoning is supported by a study that has shown that the risk of sequential slip is much lower in patients managed with immobilization in a spica cast than in those managed without immobilization in a cast[59]. Some authors have suggested that prophylactic pinning of the contralateral hip would allow these children the freedom to become more active without the constant fear of sequential slip[12]. It has also been suggested that the unpinned contralateral hip may be at more risk during the immediate postoperative period because of increased weight-bearing stresses from protecting the index hip. Having to be overly concerned with even minimal degrees of pain in the hip or knee or with imprudent activity is no doubt a source of considerable anxiety for both the child and the parents[9] and should be considered.

The duration and frequency of follow-up is debatable as well. Castro et al. found that sequential slip occurred an average (and standard deviation) of 13 ± 1 months after the index slip[1], but another author found that sequential slips occurred an average of more than three years after the index slip[58]. Of even more concern is the high frequency of asymptomatic contralateral slips. Jerre et al. reported that forty-two (71%) of fifty-nine sequential slips in their patients were asymptomatic[19].

Although the risk for development of a malignant tumor associated with radiation exposure is very small[60], with the need for frequent radiographic assessment, it is an issue that should not be overlooked. One must also be aware of the economic and social impact of multiple follow-up visits on both the patients and the families.

Another concern is limb-length discrepancy, which may actually be prevented by prophylactic pinning. Threaded screw fixation of the epiphysis has been shown to be an effective and reliable method of achieving physeal closure[47]. In theory, if growth in the proximal part of the femur in both limbs is arrested simultaneously, the amount of limb-length discrepancy should be less, provided that the index slip was not extremely severe. Several authors have also described methods of dynamic fixation that may preserve remaining growth while preventing further slip[38,39].

The risk associated with a second administration of anesthesia is a factor that should be considered as well. The risk of complications from a second anesthetic is very low, but the risk could be reduced to zero if both hips were treated simultaneously. Substantial blood loss has been associated with hardware extraction[35] but not with the procedure of in situ pinning.

In conclusion, this model should serve as a useful adjunct in the decision-making process with regard to the treatment of the contralateral hip in patients with unilateral slipped capital femoral epiphysis. It does not clearly establish the "right" method of treatment, but it does provide insight into the probability of long-term outcome for the contralateral hip on the basis of the method of treatment chosen.

The surgeon may use the data as a gross estimation of outcome, but he or she should also consider the relative risks associated with the demographic characteristics of the individual patient. Until stratified probability data can be obtained, one has to "apply" the model to each individual patient with use of sound clinical judgment. Nevertheless, the results of the sensitivity analysis suggest that the risk of sequential slip should be very low before outcome favors observation.

Finally, the preferences of the patient and the legal guardians have to be considered. Some patients may be averse to any form of short-term complication and would be willing to assume greater long-term risk. The issues of short-term complications versus long-term benefit should be discussed at great length with each patient prior to undertaking such a procedure. It should be clearly explained to patients and their families that, although there is potential for perioperative complications, the long-term functional gain can be substantial.

Appendix

eA Figures demonstrating sensitivity analyses for all variables are available with the electronic versions of this article, on our web site at www.ejbjs.org (go to the article and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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The authors did not receive grants or outside funding in support of their research or preparation of this manuscript. They did not receive payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, educational institution, or other charitable or nonprofit organization with which the authors are affiliated or associated.

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