

Improving Preoperative Risk Stratification for Intraoperative Floppy Iris Syndrome (IFIS) using Ocular Biometric Data

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Abstract

Background

Intraoperative floppy iris syndrome (IFIS) complicates cataract surgery and increases the risk of intraoperative complications. Preoperative risk assessment relies primarily on clinical history and may fail to identify susceptible patients. This study evaluated whether routinely obtained ocular biometric measurements improve preoperative prediction of IFIS.

Methods

This retrospective single-center cohort study included 1,635 eyes from 1,635 patients undergoing cataract surgery between 2022 and 2024. IFIS was identified from surgical reports, and preoperative biometric measurements were obtained by optical biometry. Complete-case multivariable logistic regression was used to compare a clinical model incorporating age, sex, and the surgeon's preoperative suspicion of IFIS with an extended model additionally incorporating axial length, anterior chamber depth, corneal radii, and mydriatic pupil diameter. Discrimination was assessed using the area under the receiver operating characteristic curve, and model performance was compared using DeLong's test.

Results

IFIS was documented in 137 eyes (8.4%). Male sex, older age, preoperative suspicion of IFIS, shallower anterior chamber depth, smaller mydriatic pupil diameter, and shorter axial length were independently associated with IFIS. An anterior chamber depth < 2.8 mm was associated with increased odds of IFIS (adjusted odds ratio 3.59; 95% confidence interval 2.04–6.34), as was a mydriatic pupil diameter ≤ 3 mm (adjusted odds ratio 3.52; 95% confidence interval 2.04–6.04). The extended model showed better discrimination than the clinical model, with areas under the curve of 0.840 (95% confidence interval 0.799–0.881) and 0.717 (95% confidence interval 0.660–0.773), respectively ($p < 0.001$).

Conclusions

Adding routinely available ocular biometric measurements to clinical predictors improved preoperative IFIS risk discrimination in this cohort. Anterior chamber depth and mydriatic pupil diameter may support risk stratification and surgical planning. Prospective evaluation and external validation are needed before routine clinical implementation.

Trial registration:

Not applicable.

Background

Cataract surgery is one of the most frequently performed and successful surgical procedures worldwide, restoring vision for millions of patients annually. Despite high success rates, intraoperative complications can occur. One of the most notable challenges is Intraoperative Floppy Iris Syndrome (IFIS), first described by Chang and Campbell in 2005 (1), is characterized by a triad of signs: a flaccid iris stroma that billows and undulates with intraocular fluid currents, a propensity for the iris to prolapse towards the phacoemulsification and side-port incisions, and progressive, often profound, intraoperative miosis.

The presence of IFIS complicates cataract surgery by obscuring the surgical field, increasing surgical time, and elevating the risk of more severe complications, such as posterior capsule rupture, vitreous loss, and retained lens fragments. The strongest and most well-established risk factor for IFIS is the systemic use of α 1-adrenergic receptor antagonists, particularly tamsulosin, which is commonly prescribed for benign prostatic hyperplasia. However, IFIS has also been associated with other medications and has been observed in patients with no known risk factors. (2–4)

Current clinical practice relies heavily on obtaining a thorough patient medication history to identify individuals at risk. The surgeon's preoperative suspicion, often noted in the patient's chart, is primarily based on a history of tamsulosin use and may also be influenced by clinical observations during slit-lamp examination, such as iridodonesis, poor pharmacologic pupil dilation, or a persistent pupillary light reflex despite pharmacologic mydriasis. While effective to a degree, this approach is subjective and may miss patients who are unaware of their full medication list or those who develop IFIS for other reasons. A more objective and quantitative method for risk stratification is therefore highly desirable.

Ocular biometry, performed routinely for intraocular lens (IOL) power calculation, provides a wealth of objective data about the eye's anatomy, including axial length (AXL), anterior chamber depth (ACD), and pupil diameter. We hypothesized that these biometric indices, which reflect the anatomical environment where IFIS manifests, could serve as independent predictors for the syndrome. The aim of this study was to develop and evaluate a predictive model for IFIS by incorporating preoperative biometric data and to compare its performance against a baseline model using demographic variables and the surgeon's preoperative suspicion of IFIS. Our ultimate goal is to create a tool that can better triage patients, identifying those who would benefit from being referred to a more experienced surgeon or scheduled in a setting conducive to managing complex cases.

Methods

Study Design and Population

We conducted a retrospective cohort study using data from patients who underwent cataract surgery at the Eye Center, Medical Center, University of Freiburg, Germany, between 2022 and 2024.

A key methodological requirement was the automated identification and linkage of intraoperative reports with preoperative biometric data. Specifically, IFIS occurrence had to be extracted from the surgical report, and the correct operated eye (right or left) had to be assigned. The identified eye was then matched to the corresponding IOLMaster biometric measurements.

Automated linkage was necessary, as manual review would have required inspection of more than 7,000 surgical reports and an equivalent number of biometric records. To ensure high data integrity, a conservative filtering strategy was applied, excluding cases whenever automated and unambiguous linkage was not possible.

During the study period (2022–2024), 10,654 cataract procedures were performed at our institution. Cases involving triple procedures with Descemet Membrane Endothelial Keratoplasty (T-DMEK) were excluded to maintain a homogeneous cohort. Additional exclusions were applied whenever automated identification of the operated eye was not feasible, linkage between the surgical report and the corresponding IOLMaster examination could not be established, or the preoperative clinical report and IOLMaster measurement were not performed on the same day, thereby ensuring an unambiguous association between biometric measurements and clinical risk assessment.

After applying all exclusion criteria, 1635 eyes from 1635 patients remained and were included in the final analysis.

The primary outcome was the presence or absence of IFIS as explicitly documented in the electronic surgical report by the operating surgeon. This binary variable (“IFIS” vs. “no IFIS”) served as the ground truth for the analysis.

Data Collection and Variables

Data were extracted from the clinic's electronic medical records. The following variables were collected:

- **Demographics:** Age at the time of preoperative assessment and patient sex (male/female)
- **Surgeon's Preoperative Assessment:** A binary variable indicating whether the surgeon had a preoperative suspicion of IFIS, based on a positive history of tamsulosin use and/or clinical observations made during slit-lamp examination, including iridodonesis, poor pharmacologic pupil dilation, and a persistent pupillary light reflex despite pharmacologic mydriasis.
- **Ocular Biometry:** Preoperative biometric measurements were obtained using an optical biometer (IOLMaster 700, Carl Zeiss Meditec). For each operated eye, we extracted the flattest and steepest corneal radii, axial length, anterior chamber depth, and mydriatic pupil diameter. Pupil measurements were taken a median of 15 minutes after instillation of mydriatic drops.
- **Exclusion Criteria:** Eyes with a history of prior intraocular surgery, traumatic cataract, or significant ocular comorbidities that could affect iris behavior (e.g., uveitis) were excluded. The final analysis was performed on a complete-case basis for all variables included in the regression models.

Predictive Modeling Strategy

The primary aim of this study was to evaluate whether routinely available ocular biometric parameters provide additional predictive value beyond standard preoperative clinical risk stratification for IFIS.

To address this question, two predictive models were defined.

A Minimal Model was constructed to represent routine preoperative clinical risk assessment and included demographic variables and the surgeon's preoperative suspicion of IFIS based on patient history.

An Elaborate Model was then developed by adding objective biometric parameters obtained from the IOLMaster to these clinical predictors. These included axial length, anterior chamber depth, corneal curvature (flattest and steepest corneal radii, r_1 and r_2), and mydriatic pupil diameter.

By comparing the performance of these two models, we aimed to determine whether biometric measurements provide incremental predictive value beyond standard clinical risk assessment.

Statistical Analysis

All statistical analyses were performed using R (R Foundation for Statistical Computing, Vienna, Austria) with the tidyverse, ggplot2, broom, Hmisc, and pROC packages.

Descriptive statistics were used to summarize the cohort characteristics. Continuous variables were presented as median and interquartile range (IQR), while categorical variables were presented as counts and percentages.

To estimate the associations between the predefined predictors and the occurrence of IFIS, multivariable logistic regression analysis was performed. The outcome variable was the intraoperative occurrence of IFIS. Predictor variables corresponded to those defined in the Minimal and Elaborate Models described above. Due to a non-linear relationship with the outcome, mydriatic pupil diameter was categorized into two groups: ≤ 3 mm and > 3 mm.

To enhance clinical interpretability, anterior chamber depth (ACD) was additionally dichotomized based on a statistically derived cut-off. A univariate receiver operating characteristic (ROC) analysis was performed for ACD, and the optimal threshold was determined using the Youden index, which maximizes the sum of sensitivity and specificity. The resulting value was pragmatically rounded to a clinically applicable cut-off of < 2.8 mm for further analyses.

The performance of both models was evaluated and compared using ROC curve analysis. The Area Under the Curve (AUC) was calculated as the primary metric of discriminative ability. An AUC of 0.5 indicates no discrimination, while an AUC of 1.0 indicates perfect discrimination. The AUCs of the two models were compared using DeLong's test. Odds Ratios (ORs) and their 95% confidence intervals (CIs)

were calculated for the predictors in the final model. A p-value of < 0.05 was considered statistically significant.

Results

Cohort Characteristics

A total of 1635 eyes were included in the cohort. The median age was 73.0 years (IQR: 65.0–79.8), and 48.6% (795/1635) were male. IFIS was documented intraoperatively in 137 eyes, for an overall incidence of 8.4%. A preoperative suspicion of IFIS was noted by the surgeon in 12.2% (200/1635) of cases.

Factors Associated with IFIS

Table 1

summarizes the characteristics of patients with and without IFIS. Patients who experienced IFIS were more likely to be male (73.7% vs. 46.3% in the non-IFIS group). They were also older (median age 76 vs. 72 years). The surgeon's preoperative suspicion was far more common in the IFIS group (35.0% vs. 10.1%). Regarding biometric parameters, eyes with IFIS had a significantly shallower anterior chamber depth (ACD 2,83mm vs 3,19mm) and a smaller mydriatic pupil diameter (< 3,18mm vs. 4,06mm) compared to eyes without IFIS.

Characteristic	No IFIS (N = 1498)	IFIS (N = 137)
Sex (% Male)	46.3% (694/1498)	73.7% (101/137)
Age (years, median [IQR])	72 [65–79]	76 [71–82]
Preop. Suspicion (% Yes)	10.1% (152/1498)	35.0% (48/137)
ACD (mm, median [IQR])	3.19 [2.89–3.45]	2.83 [2.55–3.15]
Pupil Size (mm, median [IQR])	4.06 [3.34–5.54]	3.18 [2.66–4.26]
Axial Length (mm, median [IQR])	23.74 [23.05–24.69]	23.48 [22.56–24.08]
Corneal Radius, R1 (mm, median [IQR])	7.80 [7.60–7.99]	7.80 [7.58–8.02]
Corneal Radius, R2 (mm, median [IQR])	7.63 [7.43–7.82]	7.63 [7.45–7.84]

Table 1: Characteristics of the Study Cohort by IFIS Status

Multivariable Logistic Regression

Multivariable logistic regression analysis was performed, the results are shown in Table 2 and visualized in the forest plot (Fig. 1).

After adjusting for all other factors in the model, several predictors remained significantly associated with IFIS:

- **Male sex** was the strongest demographic predictor (OR = 4.79, 95% CI [2.67–8.93], $p < 0.001$).
- **Surgeon's preoperative suspicion** remained a significant predictor (OR = 3.13, 95% CI [1.70–5.50], $p < 0.001$).
- **Anterior Chamber Depth (ACD)** Anterior chamber depth was a strong independent predictor when categorized using the data-derived cut-off. Eyes with a shallow anterior chamber (< 2.8 mm) had a significantly increased risk of IFIS (OR = 3.59, 95% CI [2.04–6.34], $p < 0.001$).
- **Mydriatic pupil diameter** was also highly significant. Eyes with a small pupil (≤ 3 mm) had a significantly increased risk of IFIS compared to those with larger pupils (OR = 3.52, 95% CI [2.04–6.04], $p < 0.001$).
- **Axial length** was additionally identified as a significant predictor. Shorter eyes were associated with a higher risk of IFIS (OR = 0.76 per mm increase, 95% CI [0.57–0.97], $p = 0.036$).

Table 2
Summary of Multivariable Logistic Regression Analysis for Predicting IFIS

Predictor	β -Coefficient	Odds Ratio	95% CI for OR	p-value
Sex (Male vs. Female)	1.5567	4.79	2.67–8.93	< 0.001
Age (per year)	0.030	1.03	1.00–1.06	0.037
Preoperative Suspicion (Yes vs. No)	1.141	3.13	1.70–5.50	< 0.001
Anterior Chamber Depth (< 2.8 mm vs ≥ 2.8 mm)	1.278	3.59	2.04–6.34	< 0.001
Pupil Size (≤ 3 mm vs. > 3 mm)	1.258	3.52	2.04–6.04	< 0.001
Axial Length (per mm)	-0.280	0.76	0.57–0.97	0.036
<i>Corneal radii were not significant and are excluded for clarity.</i>				

*ACD= Anterior chamber depth

The plot displays the odds ratios (points) and 95% confidence intervals (horizontal lines) for each predictor in the multivariable logistic regression model. An odds ratio greater than 1 indicates an increased risk of IFIS. Predictors whose confidence intervals do not cross the red dashed line (OR = 1) are statistically significant.

Model Performance Comparison

The primary goal was to assess whether the inclusion of biometric and clinical data improved predictive performance. The ROC curves for the "Elaborate Model" (demographic variables, surgeon's preoperative suspicion, ocular biometric parameters) and the "Minimal Model" (demographic and clinical predictors) are shown in Fig. 2.

The plot compares the performance of the Elaborate Model (including demographics, surgeon's suspicion, and biometrics; AUC = 0.840) and the Minimal Model (demographic and clinical predictors); AUC = 0.717). The Elaborate Model demonstrates significantly better ability to distinguish between eyes that will and will not develop IFIS.

The Elaborate Model achieved an AUC of 0.840 (95% CI: 0.799–0.881), indicating excellent discrimination. In contrast, the Minimal Model achieved an AUC of 0.717 (95% CI: 0.660–0.773). The difference in performance is substantial and statistically significant ($p < 0.001$, DeLong's test). This confirms that the addition of ocular biometric parameters provides incremental discriminative value over demographic variables and the surgeon's preoperative suspicion of IFIS.

Discussion

This study demonstrates that a predictive model incorporating objective ocular biometric data significantly improves our ability to identify patients at risk for IFIS before cataract surgery. Our final model, with significant predictors including male sex, surgeon's preoperative suspicion, anterior chamber depth, and mydriatic pupil diameter, achieved excellent predictive performance with an AUC of 0.84.

Our findings confirm previously known risk factors. The strong association with male sex and the predictive power of a surgeon's preoperative note are consistent with the literature, as both are closely linked to the use of $\alpha 1$ -antagonists for benign prostatic hyperplasia (5–8). The surgeon's suspicion is a powerful variable, as it encapsulates the crucial information from the patient's medication history. However, our model shows that even after accounting for this, objective biometric measures provide substantial, independent predictive information.

One of the most important findings of this study is the strong and independent association between anterior chamber depth and the risk of IFIS. Using a data-driven approach, we identified a clinically meaningful cut-off of < 2.8 mm, below which the risk of IFIS was significantly increased. Eyes with a shallow anterior chamber had approximately 3.6-fold higher odds of developing IFIS. A shallow anterior chamber may reflect a more crowded anterior segment configuration, which could increase the mechanical instability of the iris during phacoemulsification and thereby contribute to the characteristic iris billowing and prolapse observed in IFIS. In addition, a smaller mydriatic pupil diameter was identified as a significant risk factor for IFIS in our cohort, which is consistent with findings from previous studies (9, 10). A narrow pupil may indicate reduced dilator muscle function and impaired pharmacologic dilation, both of which are key features of the pathophysiology underlying IFIS.

The observed prevalence of IFIS in our cohort (approximately 8%) is somewhat higher than the rates reported in many previous studies, which typically range between 2% and 5% (11). Several factors may explain this difference. First, our study was conducted at a tertiary care university hospital, which functions as a regional referral center for complex cataract cases. As a result, patients with higher surgical risk profiles are more frequently referred to our institution, including individuals with multiple comorbidities or known risk factors for intraoperative complications. This referral pattern likely enriches

our surgical population with more challenging cases and may therefore increase the observed prevalence of IFIS compared with studies conducted in community-based settings or smaller surgical centers. In addition, differences in case mix, patient demographics, and documentation practices across institutions may further contribute to the variability in reported IFIS prevalence.

The strength of our study lies in the large sample size and the use of objective, machine-derived biometric data that are routinely available in modern cataract surgery workflows. Nevertheless, several limitations should be acknowledged.

First, due to the retrospective study design, the diagnosis and documentation of IFIS were not standardized. The presence of IFIS was determined based on the operating surgeon's description in the surgical report. As a result, the threshold for documenting IFIS may have varied between surgeons. Some surgeons may have recorded IFIS even in cases with relatively mild iris instability, whereas others may not have explicitly documented IFIS despite more apparent intraoperative findings or may have omitted mentioning it in the operative report. This variability in documentation may have introduced a degree of outcome misclassification.

Second, a limitation relates to the measurement of mydriatic pupil diameter. Because of the retrospective design, pupil size after mydriasis could not be assessed at a strictly standardized time point, such as after repeated instillation of mydriatic drops with a fixed waiting period to ensure maximal pharmacologic dilation. Instead, pupil measurements were obtained during routine preoperative biometry. However, in our clinical workflow the sequence of preoperative procedures is highly standardized, and in most patients IOLMaster measurements were performed approximately 15 minutes after the instillation of mydriatic drops. Although this interval is shorter than the time typically required to achieve maximal dilation, the relatively consistent timing across patients likely resulted in comparable exposure to the mydriatic agents. Consequently, the recorded pupil diameters may not represent maximal dilation but rather reflect the early dynamic response of the iris to pharmacologic stimulation. Eyes predisposed to IFIS may exhibit slower or incomplete dilation compared with normal irides, which could result in smaller pupil diameters at the time of measurement even if maximal dilation had not yet been reached.

This methodological aspect likely explains why the identified risk threshold of ≤ 3 mm may appear relatively low from a clinical perspective, as one might intuitively expect larger pupil diameters to already be associated with increased IFIS risk. However, at this early time point, smaller pupil sizes likely indicate impaired or delayed dilator muscle function, which is consistent with the underlying pathophysiology of IFIS. Consequently, the measured pupil diameter in this study should be interpreted as a functional marker of the iris response rather than as an absolute measure of maximal dilation.

Third, the analysis was limited to cases with complete biometric data, which reduced the sample size available for the final model. This may introduce a potential selection bias, although the baseline characteristics of the analyzed cohort were largely comparable to those of the overall surgical population.

Finally, this was a single-center study. Although this allowed for relatively consistent surgical techniques and clinical workflows, external validation in independent cohorts will be necessary before the proposed model can be broadly applied in other clinical settings.

The clinical implications of these findings are direct and actionable. The current standard of care relies on a binary "at-risk" versus "not-at-risk" assessment based primarily on medication history. Our model provides a more nuanced, quantitative risk score for each patient. This allows for a tiered approach to surgical planning. Patients with a low predicted probability can proceed with routine scheduling. Conversely, patients with a high score can be identified prospectively and managed accordingly:

- **Surgical Referral:** High-risk cases can be preferentially assigned to surgeons with more experience in managing IFIS.
- **Surgical Planning:** The surgeon can be prepared with necessary tools and techniques, such as iris hooks or high-viscosity viscoelastic agents
- **Scheduling:** These cases can be scheduled with more allocated time to mitigate the pressure of a busy operating list.

Future work should focus on prospective validation of this model. Furthermore, the development of a simple, integrated risk calculator—perhaps embedded within the biometry machine's software or the clinic's electronic medical record—could translate this research into a practical tool to enhance patient safety and surgical outcomes.

Conclusion

In conclusion, this study provides strong evidence that preoperative ocular biometric data, specifically anterior chamber depth (< 2.8 mm) and mydriatic pupil diameter (≤ 3 mm), are important independent predictors of intraoperative floppy iris syndrome. Incorporating objective biometric measurements, particularly anterior chamber depth (< 2.8 mm) and mydriatic pupil diameter (≤ 3 mm), into a predictive model together with established clinical predictors - including male sex, older age, and the surgeon's preoperative suspicion of IFIS - significantly improves preoperative risk stratification compared with clinical assessment alone. Although such a model cannot predict IFIS with certainty, the additional information provided by biometric parameters allows for a more refined preoperative risk estimation and may support improved surgical planning and case allocation. Future work should focus on prospective validation of this approach. Ultimately, the development of a simple, integrated risk calculator—potentially embedded within biometry software or the clinic's electronic medical record—could help translate these findings into a practical tool to further enhance patient safety and surgical outcomes.

Abbreviations

ACD

Anterior chamber depth

AUC
Area under the receiver operating characteristic curve
AXL
Axial length
CI
Confidence interval
IFIS
Intraoperative floppy iris syndrome
IOL
Intraocular lens
IQR
Interquartile range
OR
Odds ratio
ROC
Receiver operating characteristic
T-DMEK
Triple Descemet Membrane Endothelial Keratoplasty

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of the University of Freiburg and was conducted in accordance with the Declaration of Helsinki. The requirement for informed consent to participate was waived by the ethics committee due to the retrospective design and the use of anonymized data.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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This research received no funding.

Authors' contributions

MG conceived the study, designed the project, collected and analysed the data, performed the statistical analyses in collaboration with DB, interpreted the results, and drafted the manuscript. DB contributed to

the study design, supervised the statistical analyses, assisted with data interpretation, and critically revised the manuscript. TR supervised the project, provided overall scientific and clinical oversight, and critically revised the manuscript. All authors read and approved the final manuscript.

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Figures

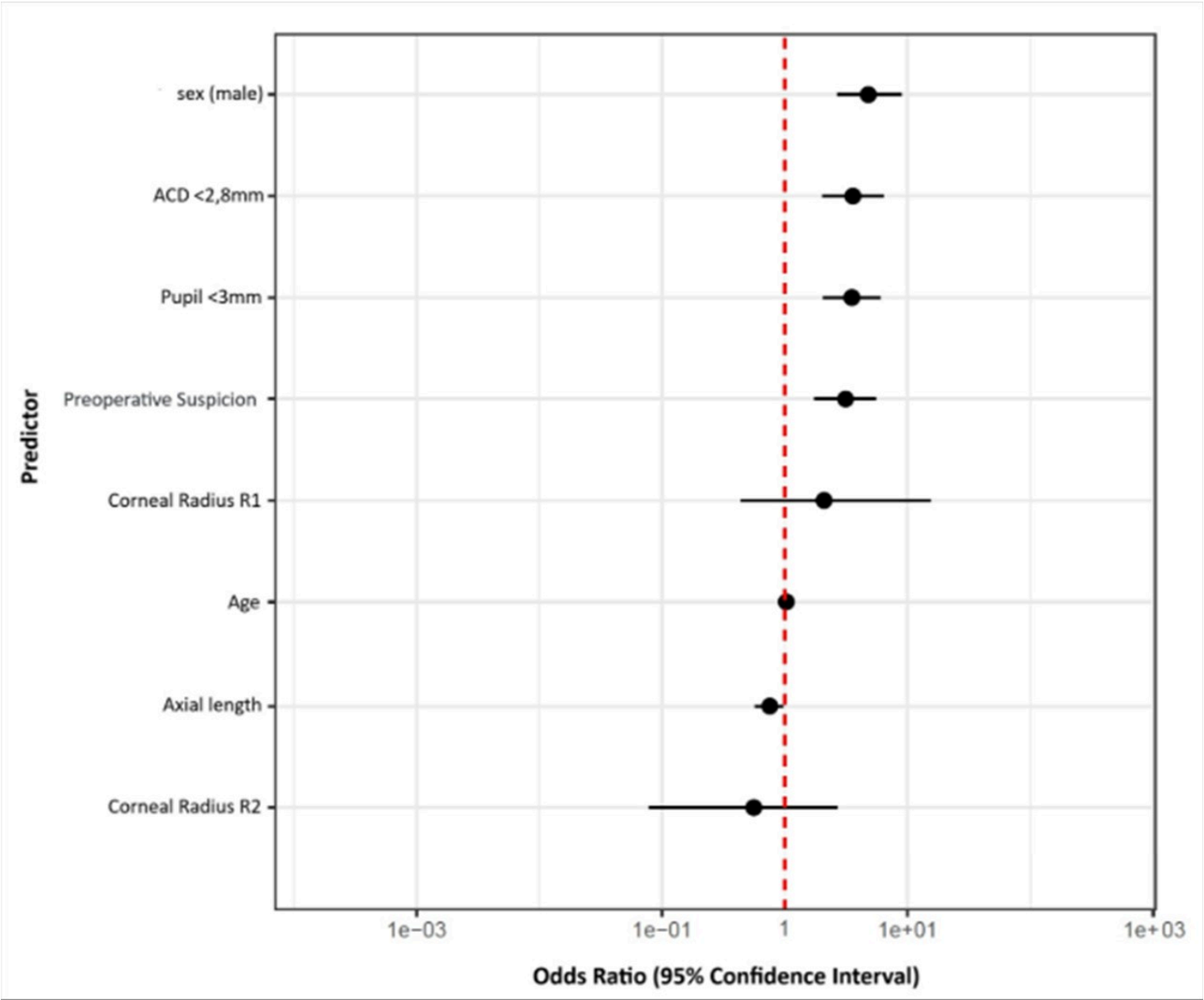


Figure 1

Forest Plot of Odds Ratios for potential IFIS-Predictors

*ACD= Anterior chamber depth

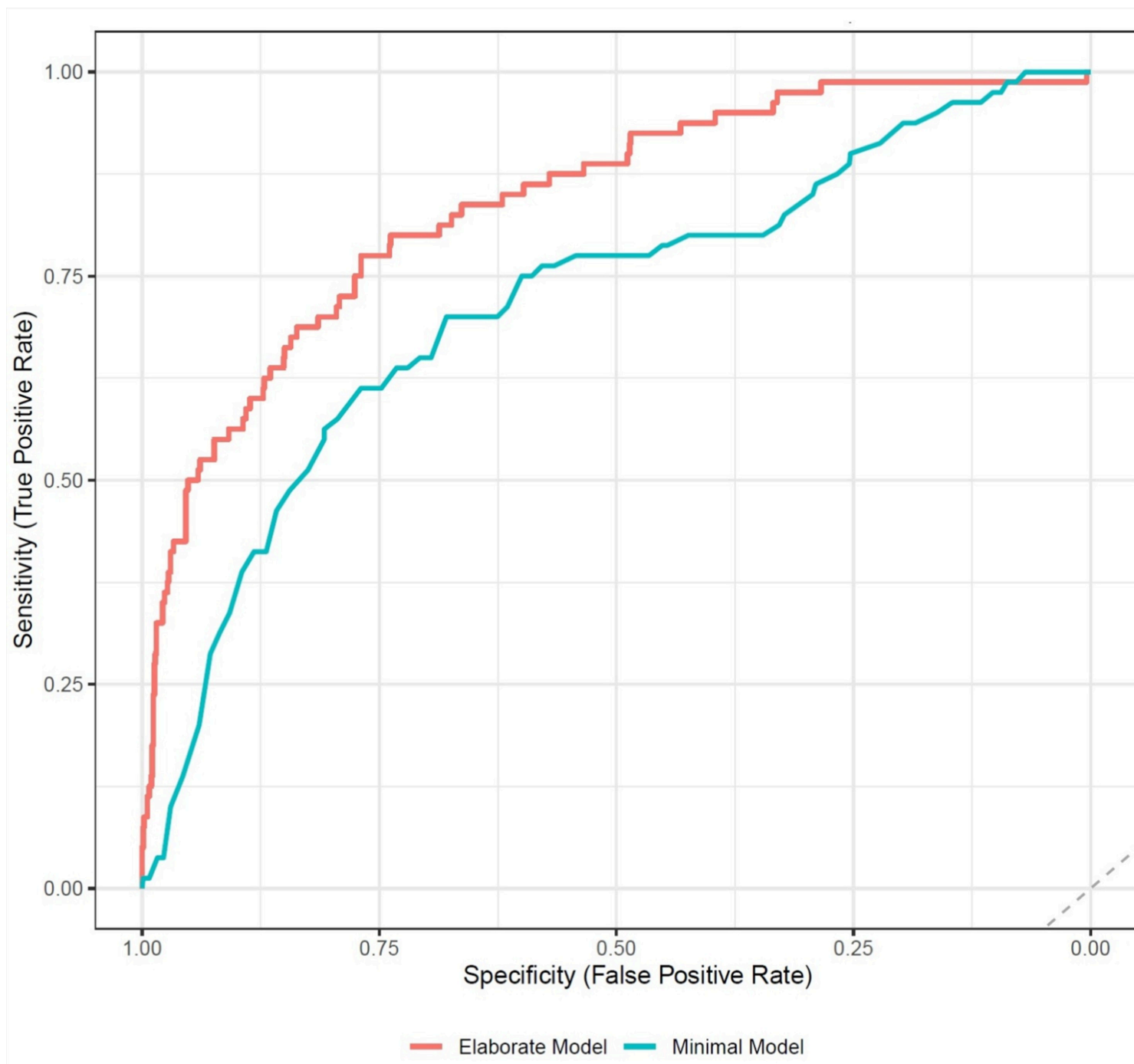


Figure 2

Receiver Operating Characteristic Curve Comparison of Predictive Performance Between Minimal and Elaborate Models for Intraoperative Floppy Iris Syndrome