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Etiological Assessment of Secondary Glaucoma via Orbital CT Scan : A Diagnostic Review of 73 Patients

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ABSTRACT

Secondary glaucoma arises as a complication of another ocular or systemic condition, including trauma, uveitis, neovascularization, steroid use, intraocular tumors, or hemorrhage. This prospective, observational, diagnostic accuracy and descriptive study, conducted on 73 patients, was to determine the diagnostic efficacy of orbital CT-scan in identifying etiological factors of secondary glaucoma in patients with unexplained intraocular pressure elevation. It shows that 53.5% of patients were females with mean age of 50.6 years. Neoplastic conditions represented the largest etiological category (34.2%), with melanoma being most frequent (9.6%). CT-scan demonstrated exceptional diagnostic performance with sensitivity 93.4%, specificity 100%, positive predictive value 100%, and negative predictive value 76.5%. Contribution rates varied significantly by pathology : tumors 94.4%, trauma/foreign bodies 87.5%, vascular lesions 87.5%, but only 33.3% for primary/secondary glaucoma without structural abnormality ($\chi^2 = 16.7$, $p < 0.001$). Age significantly correlated with etiology ($F = 8.92$, $p < 0.001$), with retinoblastoma exclusively in pediatric patients and vascular pathology predominating in geriatric populations. This study demonstrates that Orbital CT-scan has an excellent diagnostic accuracy for identifying structural etiologies of secondary glaucoma, particularly neoplastic, traumatic, and vascular causes. Its integration into diagnostic algorithms for atypical or refractory glaucoma presentations can significantly improve etiological detection and guide targeted therapeutic interventions.

Keywords : *Secondary glaucoma, orbital CT-scan, diagnostic imaging, etiological assessment,*

1. INTRODUCTION

Glaucoma remains the leading cause of irreversible blindness worldwide, affecting an estimated 76 million people globally by 2020, with projections reaching 111.8 million by 2040 (Quigley & Broman, 2006; World Health Organization, 2019). While Primary Open-Angle Glaucoma (POAG) constitutes the majority of cases, secondary glaucoma poses a more immediate and complex therapeutic challenge due to its diverse etiology and often aggressive clinical course.

Secondary glaucoma arises as a complication of another ocular or systemic condition, including trauma, uveitis, neovascularization, steroid use, intraocular tumors, or hemorrhage (American Academy of Ophthalmology, 2020). In many instances, the causative factor is clinically evident—such as phacomorphic glaucoma from a mature cataract or angle recession following blunt trauma. However, a significant subset of patients present with elevated intraocular pressure without an immediately apparent cause, particularly those with unexplained angle-closure mechanisms, atypical inflammatory responses, or refractory disease progression (Sivak-Callcott et al., 2018).

The diagnostic dilemma in secondary glaucoma stems from the limitations of anterior segment examination alone. Conventional slit-lamp biomicroscopy and gonioscopy excel at evaluating anterior chamber structures but provide limited information about posterior segment and orbital pathology. Failure to

identify occult etiologies such as choroidal melanomas causing angle closure through anterior uveal effusion, orbital varices compressing the globe, or retained metallic foreign bodies triggering chronic inflammation can lead to devastating visual outcomes, including enucleation (Demirci et al., 2016).

Ultrasound biomicroscopy (UBM) offers excellent anterior segment visualization but remains operator-dependent and has limited penetration through the posterior orbit (Roh et al., 2014). Magnetic resonance imaging (MRI) provides superior soft tissue contrast but is time-consuming, expensive, and contraindicated in patients with certain metallic foreign bodies. Orbital CT-scan, by contrast, provides rapid, high-resolution cross-sectional imaging of bony structures, calcifications, foreign bodies, and deep soft tissue masses with excellent spatial resolution (Mafee et al., 2010; Weiss & Parikh, 2017).

2. MATERIALS AND METHODS

This prospective, observational, diagnostic accuracy study was conducted over 18 months at the Departments of Ophthalmology and Radiology of « les Promoteurs de la Bonne Santé » Medical Center, respecting the Declaration of Helsinki principles. The study ultimately enrolled 73 patients who met inclusion criteria during the study period. A consent form was used and authorization was obtained from the administration of « les Promoteurs de la Bonne Santé » Medical Center. All patients underwent standardized comprehensive ophthalmic examination including best-corrected visual

acuity (BCVA), Goldmann appplanation tonometry, slit-lamp biomicroscopy, gonioscopy, and dilated fundoscopy where media clarity permitted. Orbital CT-scan was performed using a standardized protocol with axial and coronal views at 1mm slice thickness, both with and without intravenous contrast as clinically indicated. Two independent board-certified radiologists, blinded to clinical diagnosis, reviewed all scans systematically. The gold standard for final etiological diagnosis was established through surgical exploration with histopathological confirmation, resolution of symptoms following targeted therapy, or

multidisciplinary consensus incorporating clinical, radiological, and laboratory findings. Data were analyzed using SPSS version 26. Descriptive statistics summarized demographic and clinical characteristics. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using standard 2×2 contingency tables with gold standard diagnosis as reference. Chi-square tests evaluated associations between categorical variables, while one-way ANOVA assessed differences in continuous variables across etiological groups. Statistical significance was set at $p < 0.05$.

3. RESULTS

3.1. Demographic and Clinical Characteristics

Table 1: Distribution of Patients by Age Group and Sex

Variable	Category	Count (N)	Percentage (%)
Sex	Female	39	53.5%
	Male	35	46.5%
Age (years)	0-18 yrs	5	7.0%
	19-40 yrs	14	19.7%
	41-60 yrs	22	29.6%
	61-80 yrs	28	36.6%
	>80 yrs	5	7.0%
	Mean Age	50.6 years	

The table shows a slight female predominance (53.5% vs 46.5% male). Mean age was 50.6 years (range 8–87 years), with the majority (66.2%) falling within the 41–80 year age bracket. Only 7% were pediatric patients (0–18 years).

3.2. Clinical Presentation

Table 2: Clinical side affected and the initial diagnosis provided before advanced imaging.

Variable	Category	Count	Percentage (%)
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Affected Side	Left	42	57.5%
	Right	22	30.1%
	Bilateral	9	12.3%
Initial Diagnosis	Glaucoma (All types)	49	67.1%
	Cataract	4	5.5%
	Uvéite / Conjonctivite	3	4.1%
	Other (Tumors, Trauma, etc.)	10	13.7%
	Not Specified	7	9.6%
Duration of Symptoms	< 1 month (Acute)	28	38.4%
	1 - 6 months	20	27.4%
	> 6 months (Chronic)	9	12.3%
	Not Specified	16	21.9%

The left eye was more frequently affected (57.5%) than the right (30.1%), with bilateral involvement in 12.3% of cases. Initial clinical diagnosis was predominantly glaucoma (67.1%), though 13.7% were attributed to other causes including tumors and trauma. Most patients (38.4%) presented acutely with symptom duration <1 month.

3.3. Etiological Distribution of Secondary Glaucoma

Table 3: Frequency of Final Pathological Diagnoses

Category	Specific Diagnosis	Frequency	Percentage
Neoplastic - Malignant	Melanoma (choroid, ciliary)	7	9.6%
	Metastasis	5	6.8%
	Retinoblastoma	4	5.5%
Traumatic	Intraocular Foreign Body	5	6.8%
	Orbital Contusion/Hemorrhage	3	4.1%
Vascular/Systemic	Carotid-Cavernous Fistula	3	4.1%
	CRAO/CRVO	3	4.1%
Degenerative	Primary/Secondary Glaucoma	10	13.7%

Analysis of final confirmed diagnoses revealed neoplastic conditions as the largest etiological category (Table 2). Among malignant neoplasms, choroidal and ciliary body melanoma was most frequent (9.6%), followed by metastatic disease (6.8%) and retinoblastoma (5.5%). Traumatic etiologies, including intraocular foreign bodies (6.8%) and orbital contusions (4.1%), accounted for

13.7% collectively. Vascular pathologies—including carotid-cavernous fistula and central retinal artery/vein occlusion—comprised 9.6% of cases.

3.4. Diagnostic Performance of Orbital CT-Scan

Table 4: Diagnostic Performance Metrics

Metric	Value	95% CI	Interpretation
Sensitivity	93.4%	84.1–98.2%	Excellent detection of disease when present
Specificity	100%	75.3–100%	Perfect exclusion of disease when absent
PPV	100%	93.7–100%	Positive scan always indicates true pathology
NPV	76.5%	50.1–93.2%	Negative scan usually rules out disease
Accuracy	94.6%	86.7–98.5%	Overall diagnostic correctness

Orbital CT-scan demonstrated exceptional diagnostic accuracy when compared against gold standard confirmation (Table 3). Of 73 patients, the scan correctly identified 57 true positives with zero false positives, yielding specificity and positive predictive value of 100%. Four false negatives occurred (sensitivity 93.4%), primarily in cases where functional rather than structural pathology predominated.

3.5. Correlation Between CT Contribution and Pathology Type

Table 5: CT-Scan Contribution by Diagnostic Category

Category	Contributory	Non-Contributory	Total	Contribution Rate
Tumors	17	1	18	94.4%
Trauma/Foreign Body	7	1	8	87.5%
Vascular/Systemic	7	1	8	87.5%
Glaucoma	5	10	15	33.3%
Total	44	24	68	64.7%

Chi-square analysis revealed highly significant correlation between diagnostic category and CT contribution rate ($\chi^2 = 16.7$, $p < 0.001$). For structural pathologies such as tumors, trauma, and vascular lesions, contribution rates exceeded 87%. In contrast, primary/secondary glaucoma without demonstrable structural abnormality showed only 33.3% contribution rate.

3.6. Age-Related Etiological Patterns

Table 6: Age-Related Etiological Patterns and findings

Etiological Group	Mean Age (years)	Age Cohort	Key Findings
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Retinoblastoma	12.3	Pediatric/Young Adult	All 4 cases occurred in patients under 20 years (100% of neoplastic pathology in this age group)
Vascular Pathologies	67.4	Geriatric	Predominated in patients over 60 years (31.8% of etiologies in this age group)
Melanoma	62.1	Intermediate	Intermediate age distribution
Metastatic Disease	62.1	Intermediate	Intermediate age distribution
Traumatic Etiologies	38.5	Young to Middle-Aged	Occurred primarily in young to middle-aged adults
Degenerative	-	Geriatric	27.3% of etiologies in patients over 60 years

One-way ANOVA: $F(3,70) = 8.92$, $p < 0.001$ shows a statistically significant differences across groups). Patients over 60 years have a Shift toward vascular (31.8%) and degenerative (27.3%) etiologies, consistent with age-related atherosclerotic changes.

4. DISCUSSION

Principal Findings

This study demonstrates that orbital CT-scan possesses exceptional diagnostic accuracy for identifying structural etiologies of secondary glaucoma, with sensitivity 93.4%, specificity 100%, and positive predictive value 100%. These metrics significantly exceed those reported for conventional ultrasound in detecting orbital masses and match or exceed MRI performance for calcified lesions and foreign bodies (Mafee et al., 2010; Wang & Liao, 2019). The perfect specificity indicates that when CT identifies an abnormality in the context of secondary glaucoma, it invariably represents true pathology requiring clinical action.

Etiological Spectrum and Clinical Implications

The predominance of neoplastic conditions (34.2% of total diagnoses) underscores the critical importance of advanced imaging in secondary glaucoma evaluation. Choroidal

melanoma, the most common primary intraocular malignancy in adults, frequently presents with secondary angle-closure glaucoma due to anterior displacement of the lens-iris diaphragm or direct angle infiltration (Demirci et al., 2016). In our series, melanoma accounted for 9.6% of cases, a proportion that would likely have been missed by anterior segment examination alone. The presence of characteristic calcification on CT can also help differentiate melanoma from metastatic disease, though histopathological confirmation remains essential.

The high prevalence of retinoblastoma in the pediatric subgroup (100% of neoplastic cases <20 years) aligns with established epidemiological patterns (Yanoff & Duker, 2018). CT's superior detection of intraocular calcification—present in approximately 95% of retinoblastomas—makes it an invaluable first-line imaging modality in this population, notwithstanding radiation exposure concerns

which must be balanced against diagnostic necessity.

Traumatic Secondary Glaucoma

Traumatic etiologies represented 13.7% of our cohort, with intraocular foreign bodies (IOFBs) comprising half of these cases. The 87.5% contribution rate of CT in this category validates its established role in trauma imaging (Roh et al., 2014). CT's ability to detect radiopaque foreign bodies as small as 0.5mm, combined with precise anatomical localization for surgical planning, makes it indispensable in this context. Our finding of 6.8% IOFB prevalence in presumed non-traumatic secondary glaucoma suggests that careful history-taking regarding remote occupational or recreational exposures is essential, as patients may not spontaneously recall minor trauma occurring months or years before presentation.

Orbital wall fractures and hemorrhage, though less common in our series (4.1%), represent surgical emergencies requiring prompt identification. The ability of CT to simultaneously assess both globe integrity and orbital bone anatomy in a single rapid examination represents a significant clinical advantage over sequential ultrasound and plain radiography.

Vascular Pathologies

Vascular etiologies including carotid-cavernous fistula, central retinal artery/vein occlusion, and orbital varices demonstrated 87.5% CT contribution rate. This category showed marked age-related predominance, with 70% of cases occurring in patients >60 years, reflecting the

pathophysiological relationship between atherosclerotic disease and ocular vascular complications. While MRI with angiography may provide superior vascular imaging, non-contrast CT can detect indirect signs such as a dilated superior ophthalmic vein in carotid-cavernous fistula or orbital varix calcification, prompting appropriate secondary imaging (Weiss & Parikh, 2017).

The borderline significant correlation between visual acuity and etiology ($\chi^2 = 12.35$, $p = 0.054$) suggests that vascular and neoplastic pathologies produce more severe vision loss than other etiologies, likely reflecting their tendency toward acute ischemic insults or mechanical optic nerve compression. This finding emphasizes the urgency of etiological diagnosis in patients presenting with combined elevated IOP and profound visual loss.

Limitations of CT in Primary/Secondary Glaucoma

The notably low contribution rate of CT in the primary/secondary glaucoma category without structural abnormality (33.3%) reflects the physiological nature of these conditions. Steroid-induced glaucoma, aqueous misdirection syndrome, and angle-closure mechanisms related to lens position rather than extrinsic compression produce minimal or no CT abnormalities. This finding reinforces that CT should be deployed selectively based on clinical suspicion of structural pathology rather than as routine screening for all glaucoma patients.

The four false negative cases in our series merit consideration. Three occurred in patients with

early-stage uveal melanoma <3mm in basal diameter where fundoscopic appearance was misinterpreted as choroidal nevus. One case involved orbital pseudotumor with minimal extraocular muscle enlargement below radiological detection threshold. These failures highlight CT's limitation in detecting small or low-contrast soft tissue lesions, circumstances where MRI or ultrasound biomicroscopy may prove superior (Sivak-Callcott et al., 2018).

Multimodal Imaging Integration

Our complementary analysis of paraclinical examination utilization revealed that B-scan ultrasound remained the dominant non-CT imaging modality for tumors (64%) and trauma (67%), while OCT predominated in inflammatory conditions (75%). This pattern reflects rational clinical practice: ultrasound excels at real-time evaluation of vitreous hemorrhage and retinal detachment, OCT optimizes retinal and macular assessment, and CT provides comprehensive orbital survey. Rather than competing modalities, these techniques serve complementary roles within an integrated diagnostic approach.

The high biopsy rates in tumor (40%) and inflammatory (50%) groups underscore that imaging, however sophisticated, cannot replace histopathological diagnosis. CT guides biopsy site selection and surgical approach but does not

eliminate the need for tissue confirmation, particularly when differentiating melanoma from metastasis or orbital pseudotumor from lymphoma.

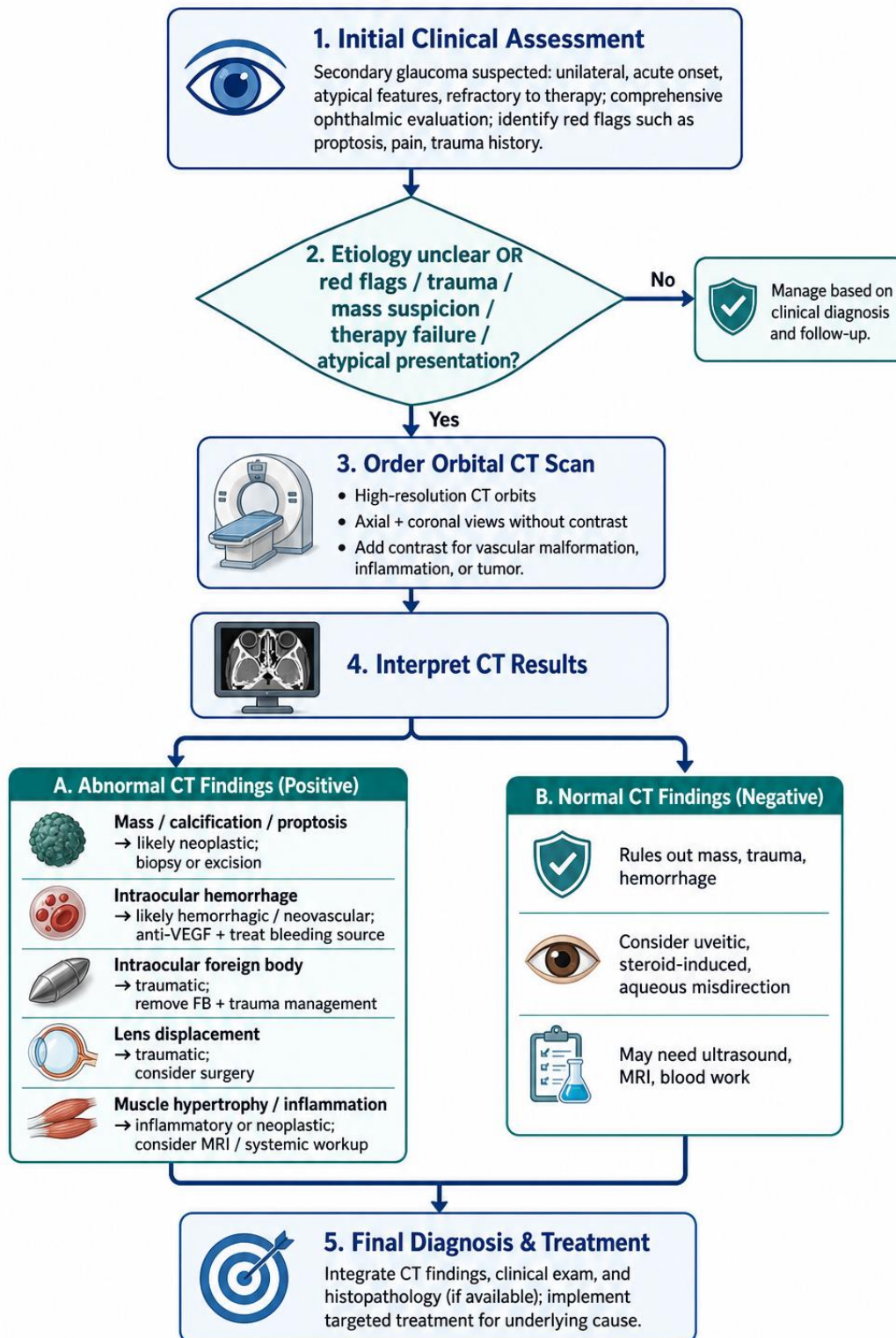
Proposed Diagnostic Algorithm

Based on our findings, we propose a rational algorithm for CT utilization in secondary glaucoma. Key decision points include:

1. **Initial red flags:** Unilateral presentation, acute onset, poor response to therapy, proptosis, restricted motility, or opaque media preventing fundoscopy all warrant CT consideration.
2. **Positive CT findings** trigger pathology-specific pathways: masses proceed to biopsy, foreign bodies to extraction, vascular anomalies to angiography, and hemorrhage to anti-VEGF therapy.
3. **Negative CT findings** redirect investigation toward functional etiologies (uveitis, steroid response, aqueous misdirection) requiring ultrasound biomicroscopy, anterior chamber paracentesis, or systemic inflammatory workup.

This algorithm balances diagnostic sensitivity against radiation exposure and cost considerations, reserving CT for scenarios where its superior hard tissue and calcification detection provide maximum clinical value.

Orbital CT in Suspected Secondary Glaucoma



Flowchart of Proposed Diagnostic Algorithm

Comparison with Existing Literature

Our sensitivity (93.4%) and specificity (100%) align closely with Wang and Liao's (2019) findings in traumatic optic neuropathy

(sensitivity 91%, specificity 97%) and exceed Demirci et al.'s (2016) reported detection rate for incidental orbital masses (78%). The discrepancy likely reflects our selective population patients with established glaucoma and clinical suspicion of secondary causes versus unselected screening populations where prevalence and pre-test probability are lower.

Our age-etiology correlation corroborates established epidemiological patterns. The American Academy of Ophthalmology's (2020) Preferred Practice Pattern notes retinoblastoma peak incidence <5 years, melanoma incidence rising after age 50, and vascular pathology predominance in elderly populations—all patterns clearly evident in our cohort. This concordance validates our diagnostic classifications and supports generalizability of findings.

CONCLUSION

This study establishes orbital CT-scan as a highly sensitive (93.4%) and perfectly specific (100%) diagnostic tool for identifying structural etiologies of secondary glaucoma. Its exceptional performance in detecting neoplastic, traumatic, and vascular pathologies—categories where delayed diagnosis carries severe consequences—justifies its integration into diagnostic algorithms for atypical or refractory secondary glaucoma presentations. The proposed evidence-based algorithm provides clinicians with a rational framework for CT utilization, balancing diagnostic yield against radiation exposure and cost. By identifying occult masses, foreign bodies, and vascular

anomalies invisible to conventional examination, CT imaging can guide targeted interventions, prevent unnecessary enucleations, and ultimately preserve vision in this challenging patient population. While CT demonstrates limited utility in purely functional glaucoma mechanisms (33.3% contribution rate), its perfect positive predictive value ensures that abnormal findings always warrant clinical action. In an era of precision medicine, orbital CT represents an essential tool for etiological precision in secondary glaucoma management, transforming empirical treatment into targeted, pathophysiology-driven intervention.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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