Artificial intelligence-based referral and progression of diabetic kidney disease using retinal fundus images

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PURPOSE

- Diabetic kidney disease (DKD) is a chronic condition of prolonged diabetes, and there is a pressing need to detect at an early stage. Past studies have substantiated diabetic retinopathy (DR) as a strong predictor of risk for DKD. But none have investigated noninvasive staging and progression.
- Machine learning techniques were utilized to predict stage of DKD through retinal fundus images and clinical parameters refer the outcome of predictions to a nephrologist for renal assessment.

METHODS

- The referral workflow to nephrologist consisted of identifying DR and DKD stages (Figure 1).
- Participants: 970 patients' fundus photographs and noninvasive clinical parameters such as History of hypertension (Yes/No), Urine protein, Age, Gender, Other comorbidities (cardiac diseases, sepsis, peripheral diseases, urinary tract infection, peripheral neuropathy, edema, etc.), diabetes duration.
- Each patient had multiple visits and visit date of creatine value collected <= 1 year from ophthalmic data collected date were selected. Closest visit with creatine date collected to diabetic visit were mapped. Each visit at eye level observation were Independent and Identically distributed.
- A deep learning algorithm was developed to classify the DR stages into severe, mild, and no DR. The DR classifier was based on pathologies such as microaneurysm(s),dot/blot hemorrhages, hard exudates, cotton wool spots, intraretinal hemorrhages, venous beading, intraretinal microvascular abnormalities, neovascularization, vitreous /preretinal hemorrhage (Figure 2).
- The predicted DR stages, exudates, cotton wool spots, and non-invasive clinical parameters were fed as an input to second deep learning model to predict the stage (i.e., early, late) of kidney disease (Figure 2).
- A third deep learning algorithm then predicted the progression of the kidney disorder to rapid, slow, or no progression based on staging information, and non-invasive nephrological parameters.
- The algorithm also performed an internal mapping between DR stages and pathologies extracted from retinal fundus images (Table 1).

CONCLUSIONS

This study demonstrates a potential to detect DKD at an early stage in patients with diabetes. This method provides the ophthalmologist with an additional decision-making support on whether to refer the patient to nephrologist based on the staging of kidney disorder.

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RESULTS

The sensitivity of DR classifier was 88%. The sensitivity and specificity of the referral workflow were 79%, and 86%. The efficacy of the referral algorithm was AUC: 86% . Further, the sensitivity of baseline progression was found to be 82%. The results show strong correlation between DR and DKD stages.

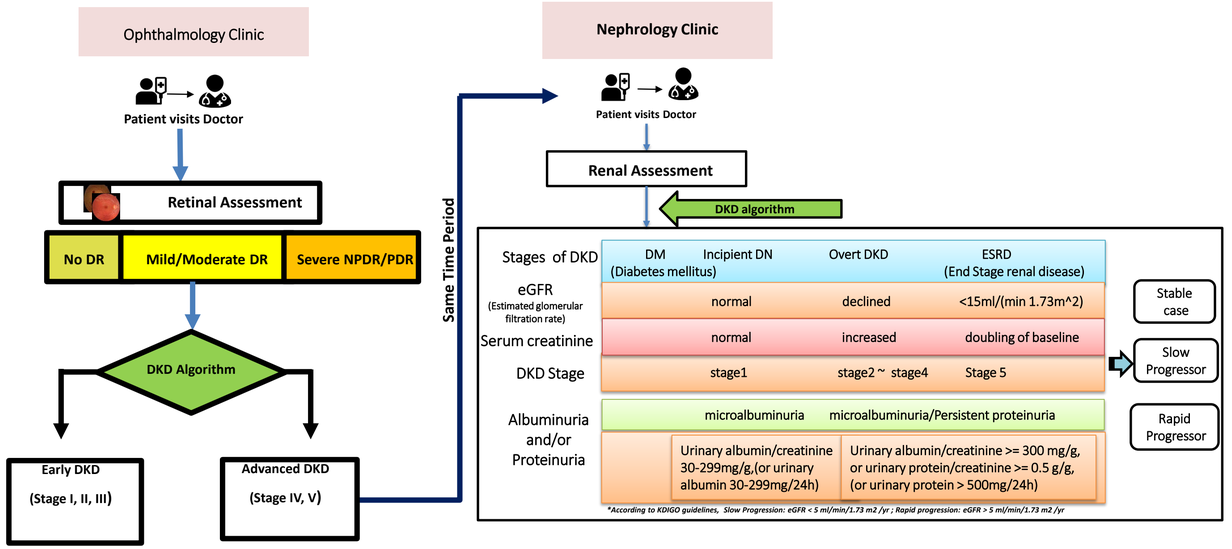

Figure 1.Illustrates diabetic kidney disease staging and progression workflow

DR Stages	Pathologies
No DR	No abnormalities
Mild non proliferative DR	Microaneurysms
Moderate non-proliferative DR	Microaneurysm(s), Dot/Blot hemorrhages, Hard Exudates, Cotton wool spots
Severe non-proliferative DR	Microaneurysm(s), Dot/Blot hemorrhages, Hard Exudates, Cotton wool spots, Intraretinal hemorrhages, Venous beading, Intraretinal microvascular abnormalities
Proliferative DR	Microaneurysm(s),Dot/Blot hemorrhages, Hard Exudates, Cotton wool spots, Intraretinal hemorrhages, Venous beading, Intraretinal microvascular abnormalities, Neovascularization, Vitreous /Preretinal hemorrhage

Table 1. DR stage to fundus pathology mapping

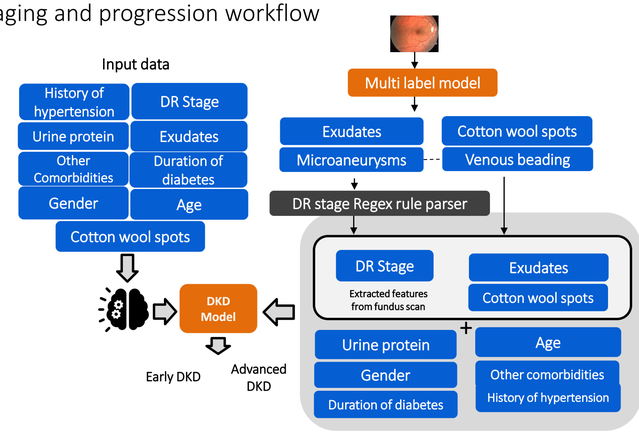

Figure 2. Pathologies, demographics, and clinical parameters used for model training