

The Montrachet Study: study design, methodology and analysis of visual acuity and refractive errors in an elderly population

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ABSTRACT.

Purpose: To describe the design of the Montrachet Study (Maculopathy Optic Nerve nuTRition neurovAsCular and HEarT diseases) and to report visual acuity and refractive errors in this elderly population.

Methods: Participants were recruited in Dijon (France), from the ongoing population-based 3C Study. In 2009–2011, 1153 participants from the 3 Cities Study, aged 75 years or more, had an initial eye examination and were scheduled for eye examinations. The eye examination comprised visual acuity, refraction, visual field, ocular surface assessment, photographs and OCT of the macula and the optic disc, measurement of intra-ocular pressure, central corneal thickness and macular pigment assessment. Information on cardiovascular and neurologic diseases and a large comprehensive database (blood samples, genetic testing, cognitive tests, MRI) were available from the 3C Study.

Results: Presenting visual acuity <20/60 in the better eye was found in 2.3% (95% CI 1.5–3.2) of the participants with no gender differences. Visual impairment increased with age from 1.5% (95% CI 0.3–2.7) for those aged 75–79 years to 5.6% (95% CI 2.9–8.4) for patients 85 years and older ($p = 0.0003$). Spherical equivalent did not differ between men and women ($p = 0.8$) and decreased with age whatever the lens status.

Conclusion: Despite the high prevalence of self-reported eye diseases in this elderly population, visual impairment was low and increased with age. The Montrachet Study may help to better estimate the prevalence of eye diseases in people over 75 years of age and to seek associations with cardiovascular and neurologic diseases and their potential risk factors.

Key words: cardiovascular diseases – elderly – eye diseases – neurologic diseases – nutrition – population-based study

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Introduction

One of the main characteristics of today's modern societies is that life expectancy has dramatically increased over the last few decades. In fact, mortality has been postponed with the improvement of health, which is mainly due to prosperity and modern medicine (Vaupel 2010). It is estimated that most children born since 2000 will become centenarians because survival and health are continuously improving in the elderly (Christensen et al. 2009). In the meantime, the prevalence of most eye diseases increases with age as does the prevalence of low vision and blindness (Klein & Klein 2013a,b). The burden of these conditions is a great challenge today and in the future for healthcare services and health professionals, but also for caregivers and payers (Klein & Klein 2013a,b). The Eye Diseases Prevalence Research Group estimated that in the USA between 2000 and 2020 the prevalence of cataract, open-angle glaucoma and late age-related macular degeneration (AMD) will increase by 50% and low vision and blindness by 63% and 78%, respectively (Klein & Klein 2013a,b). Individuals 80 years of age and over are most impacted by age-related eye diseases because they account for one-third of all cases of cataract, open-angle glaucoma and

early AMD and two-thirds of late AMD (Klein & Klein 2013a,b). When comparing 18- to 44-year-olds to those 75 years and older, visual impairment and blindness follow the same trend, with a fourfold and sevenfold increase, respectively (Klein & Klein 2013a,b). Visual impairment and blindness are strongly related to ageing, and it has been reported that worldwide people 50 years and older account for 65% and 82% of the visually impaired and blind, respectively (Pascolini & Mariotti 2011).

Most population-based studies have investigated a wide age range. Some of them have specifically focused on the elderly (Fisher et al. 2015; Meuer et al. 2015), and some large studies have gathered a representative sample of the elderly (Attebo et al. 1996; Rubin et al. 1997; Klaver et al. 1998). Only two population-based studies have described the ocular status of an old French population, Pola (Pathologies Oculaires Liées à l'Age) and Alienor (Antioxydants, Lipides Essentiels, Nutrition et maladies Oculaires), conducted in the south and the southwest of France, respectively (Delcourt et al. 1998, 2010).

The Montrachet (Maculopathy Optic Nerve nuTRition neurovAsCular and HEarT diseases) Study is a population-based study designed to find associations between age-related eye diseases and neurologic and heart diseases in the elderly as a primary objective. The secondary objective was to report the prevalence of the main age-related eye diseases in the elderly as well as the influence of genetic and environmental risk factors. In this article, we report on the methodology and baseline characteristics of the Montrachet Study and describe visual impairment and refractive errors in this elderly population.

Material and Methods

Participants of the Montrachet Study were recruited from an ongoing population-based study, the Three-City (3C) Study, which examined the vascular risk factors for dementia (2003). The 3C Study was designed to examine the relationship between vascular diseases and dementia in 9294 community-dwelling persons aged 65 years and over. The participants were selected from the electoral rolls and were only

urban as they lived in three French cities: Bordeaux, Dijon and Montpellier. The 3C Study began in 1999, and participants were evaluated every 2 years thereafter. Eye examinations were proposed to 3C participants from 2006 in Bordeaux (Alienor Study) (Delcourt et al. 2010) and from 2009 in Dijon (Montrachet Study).

In Dijon, 4931 participants participated in the first run of the 3C Study in 1999. At the fifth run, a subgroup of participants was invited to participate in the Montrachet Study (Fig. 1). The study was approved by the regional ethics committee and was registered as 2009-A00448-49. All participants gave their informed consent, and the study followed the tenets of the Declaration of Helsinki. We preferentially chose the participants who had had an MRI ($n = 1663$), and we completed the recruitment with a random sample of 500 participants without MRI. Therefore, from 22 October 2009, until 31 March 2013, 900 volunteers with an MRI and 253 without an MRI were recruited in the Montrachet Study.

Participants were called by technicians and stayed about 3 h in the Department of Ophthalmology. Fasting blood samples were drawn to measure plasma carotenoids and fatty acids. Technicians conducted the eye examination in the Department of Ophthalmology, University Hospital Dijon, France. They were trained before the study and every year after by senior ophthalmologists. An ophthalmologist checked the data with the technicians every month. At the end of the eye examination, participants were asked to fill in a questionnaire at home about lifestyle, environment and nutrition (food frequency questionnaire). The following data were collected.

Ophthalmic history

Self-reported date of the last visit to an ophthalmologist, cataract, AMD, glaucoma, diabetic retinopathy, dry eye and previous ocular procedures (laser and surgery) was noted. Participants were also questioned about ocular treatments (local or systemic) and nutritional supplements. Family history was also collected and was focused on glaucoma, ocular hypertension and AMD.

Visual acuity

Presenting visual acuity (VA) with the participant's glasses and best-corrected visual acuity according to the autorefractor were measured. Monocular visual acuity was evaluated with EDTRS charts in a light box (Light House Low Vision, New York, NY, USA) at 4 m for far VA and the number of letters read was recorded. For participants unable to read three letters, they were tested for counting fingers at 30 cm, hand motion, light perception or blindness. Near visual acuity was measured with Parinaud charts (Luneau SAS, Chartres, France), the test currently used in France. Visual impairment was defined as VA in the better eye $< 20/60$ and blindness as VA $< 20/200$ according to WHO criteria (Hong et al. 2014).

Refractive error

Refractive error was determined using an autorefractor without cycloplegia (Tonoref II, Nidek, Aichi, Japan). The sphere, the cylinder (minus cylinder) and the axis were noted as well as the keratometry. Spherical equivalent (i.e. the sum of the sphere + half the cylinder) was recorded for both eyes. Myopia was defined as a spherical equivalent (SE) < -0.5 D, hyperopia as a spherical equivalent $> +0.5$ D and emmetropia was between -0.5 D and $+0.5$ D as described by others (Attebo et al. 1999; Wolfram et al. 2014). High myopia and high hyperopia were defined by SE < -5 D and SE > 5 D, respectively (Attebo et al. 1999). Three patients having had a corneal graft were excluded from the analysis.

Tonometry and pachymetry

Intra-ocular pressure (IOP) was measured by air tonometry (Tonoref II, Nidek, Aichi, Japan), and central corneal thickness (CCT) was measured with an ultrasonic contact pachymeter (DGH 500, DGH Technology, Exton, PA, USA); the mean of three consecutive measurements was recorded for each eye.

Slit-lamp examination and ocular surface evaluation

Slit-lamp biomicroscopy was performed to identify pseudophakic eyes.

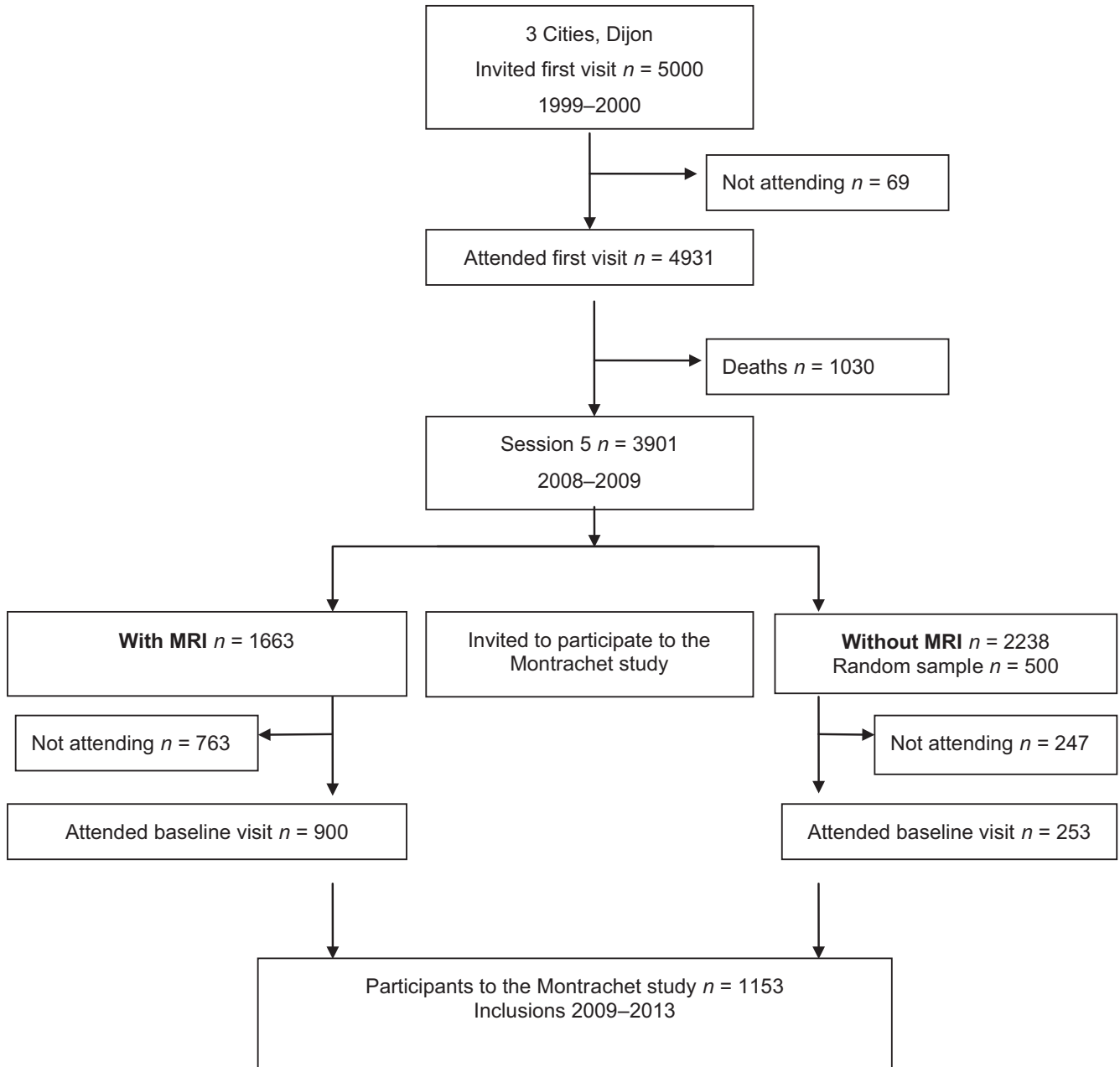


Fig. 1. Flow chart showing the recruitment of participants in the Montrachet study.

Symptoms were evaluated by the Ocular Surface Disease Index (OSDI) questionnaire (Schiffman et al. 2000). A Schirmer I test measured in millimetres was performed without anaesthesia, and paper strips (Lipo-sic-Schirmer-Test-Streifen; Dr Mann Pharma, Berlin, Germany) were removed from the lower fornix after 5 min. The tear film break-up time expressed in seconds was evaluated after instillation of one drop of fluorescein (Fluorescéine Faure 0.5% single dose, Novartis, Rueil-Malmaison, France). The average of three measurements was recorded. Corneal

staining was recorded with the Oxford scale.

Visual field

After the participants were carefully informed on the nature of the test by a trained technician, a visual field examination was performed by frequency doubling perimetry with the screening program C-20-5 (Carl Zeiss Meditec, Dublin, CA, USA). The test was considered valid if the rate of false-positive results and fixation loss were $\leq 33\%$. An abnormal frequency doubling perime-

try was defined as at least one location of reduced sensitivity of any level (Wang et al. 2012).

OCT imaging

A spectral domain optical coherence tomography (Spectralis, Heidelberg Engineering Co., Heidelberg, Germany) was performed both for the macula and the optic nerve head after pupil dilation. The high-speed resolution mode and the eye-tracking system were activated for acquiring the images. For the macula, an OCT image

was obtained with a $20^\circ \times 15^\circ$ pattern size, 19 B-scans spaced $235 \mu\text{m}$ apart and the ART mode on. For the retinal nerve fibre layer evaluation, circular B-scans (3.4 mm in diameter, 768 pixels, 1536 A-scans/s) were automatically centred on the optic disc. The Spectralis OCT software, Heidelberg Explorer (HEE, version 5.3; Heidelberg Engineering Co., Heidelberg, Germany) was used for the automatic segmentation of the retinal nerve fibre layer (RNFL) and for the calculation of the mean RNFL thickness in six sectors of the peripapillary region (Zhao et al. 2014).

Macular pigment assessment

Macular pigment optical density (MPOD) was measured with a modified Heidelberg Retinal Angiograph (HRA) (Spectralis, Heidelberg Engineering Co.). Sequences of 20° images were captured at 488 and 514 nm after retinal bleaching (Trieschmann et al. 2007). MPOD maps were generated by digital subtraction of the log AF images. We recorded MPOD at 0° and at eccentricities of 0.5° , 1.0° , 2.0° and 6.0° , using the software provided by the manufacturer of the device (Creuzot-Garcher et al. 2014). MPOD was expressed in optical density units (DU).

Retinal photographs

Two 45° colour retinal photographs (one centred on the macula and one on the optic disc) were recorded with a fundus camera (TRC NW6S, Topcon, Tokyo, Japan) after pupil dilation with tropicamide 0.5% (Théa, Clermont-Ferrand, France).

Statistics

Data were recorded on a secured database (Microsoft Access), and automatic controls for missing or incoherent data were regularly applied. Quantitative variables were reported using mean \pm standard deviation (SD) or median [interquartile range (IQR)] depending on their distribution (tested using the Shapiro–Wilk test) and qualitative variables as a percentage and 95% confidence interval.

Participants were compared to non-participants using appropriate bivariate tests (chi-square test for percentage

comparisons; analysis of variance or Kruskal–Wallis test for mean (or median) comparisons). A chi-square test for trend was used for the comparison of age categories. The Spearman correlation coefficient was used for bivariate analysis. A p-value below 0.05 was considered significant for all analyses. They were calculated using Stata v12 (StataCorp, College Station, TX, USA).

Results

The participants of the Montrachet Study represented 54.1% and 50.6% of the cohort still followed in Dijon 10 years after the initiation of the 3C Study, for those having had an MRI and those without MRI, respectively (Fig. 1). All the individuals were Caucasians, and the mean age at inclusion in the Montrachet Study was 82.2 ± 3.8 years; the age ranged from 75.6 to 96.2 years and 62.7% were females. Table 1 displays the main differences of the parameters recorded at the initiation of the 3C Study between Montrachet participants and non-participants. Overall, the Montrachet population was younger at inclusion in the 3C Study and had better health markers than non-participants; the BMI, systolic blood pressure and blood sugar were lower. Montrachet participants had fewer cardiovascular diseases, fewer neurologic conditions, less diabetes and greater autonomy with a higher level of education compared with the non-participants. When we adjusted for age and sex, only the mean diastolic blood pressure and the number of falls were no longer statistically significant, $p = 0.72$ and $p = 0.41$, respectively. The self-reported eye diseases and procedures are given in Table 2. Dry eye and cataract extraction were the most frequent events reported in this population. The median time for the last visit to an ophthalmologist before inclusion in the study was 12 [0; 24] months, and 83.9% of the participants had had an eye examination by an ophthalmologist within the past 3 years before participating in the Montrachet Study.

Presenting visual acuity (PVA) and best-corrected visual acuity (BCVA) in the better eye are displayed in Table 3. The crude prevalence of PVA and BCVA $< 20/60$ was 2.3% (95% CI 1.5–3.2) and 1.8% (95% CI 1.1–2.6),

respectively. The crude prevalence of PVA and BVA $< 20/40$ was 8.7% and 3.9%, respectively. The prevalence of visual impairment ($< 20/60$) did not vary for either visual correction tested, PVA or BCVA, $p = 0.39$, while this difference was statistically significant when taking into account a threshold of $20/40$, $p < 0.0001$. Overall, there were no differences according to gender ($p = 0.83$), while visual impairment increased significantly with age, Table 3. Seven participants (0.6%) were blind according to WHO criteria, and this prevalence did not increase in older participants.

Refractive errors are shown in Table 4. The Spearman correlation coefficient between eyes for the SE was 0.78; therefore, the results for the right eye were considered for analysis. Globally, SE was similar in men and women ($p = 0.87$) and decreased slightly with age regardless of the lens status from a median [IQR] 0.38 D [−0.75; 1.56] below 80 years of age to −0.44 D [−1.25; 0.47] over 84 years, $p < 0.0001$. Refractive errors did not follow a linear trend with age whatever the lens status, Table 4. Hyperopia was mainly found in phakic eyes and decreased in participants 85 years and older, Table 4. In pseudophakic participants, SE was lower than in phakic individuals, −0.38 D [−1.38; 0.13] versus 1.00 D [−0.50; 2.00], respectively, $p < 0.0001$. High myopia and high hyperopia were found in 2.2% and 1.6% of the study population, respectively.

Discussion

The 20th century was marked by a gain of about 30 years in life expectancy in Western Europe, the USA, Canada, Australia, New Zealand and Japan (Christensen et al. 2009). Senescence could be regarded as an imbalance between damage and repair (Vaupel 2010). However, it has been shown that most age-related conditions which could affect the quality of life in the elderly are more often moderate than severe (Cambois et al. 2012). It is well documented that most parts of the eye are affected by ageing. Interestingly, these age-related eye diseases are often combined with systemic diseases such as diabetes or cerebrovascular diseases and therefore have translational application to other systems of the human

Table 1. Comparison of the main characteristics of participants and non-participants in the Montrachet study.

| | Non-participants (<i>n</i> = 3778) | Participants (<i>n</i> = 1153) | p-value |
|----------------------------|-------------------------------------|---------------------------------|---------|
| Demographics | | | |
| Age | 75.7 ± 5.8 | 71.2 ± 3.8 | <0.001 |
| Sex | | | |
| Male | 1458 (38.6) | 430 (37.3) | 0.43 |
| Female | 2320 (61.4) | 723 (62.7) | |
| BMI | | | |
| <25 kg/m ² | 1738 (46.4) | 594 (51.5) | <0.001 |
| 25–30 kg/m ² | 1455 (38.9) | 440 (38.2) | |
| >30 kg/m ² | 550 (14.7) | 119 (10.3) | |
| Education | | | |
| Less than O-level | 109 (2.9) | 14 (1.2) | <0.001 |
| O-level | 2518 (66.6) | 678 (58.8) | |
| A-level | 454 (12.0) | 155 (13.5) | |
| Degree | 697 (18.5) | 306 (26.5) | |
| Alcohol status | | | |
| Never | 771 (20.7) | 191 (17.0) | 0.016 |
| Former | 95 (2.6) | 26 (2.3) | |
| Current | 2851 (76.7) | 909 (80.7) | |
| Smoking status | | | |
| Never | 2302 (61.0) | 738 (64.0) | 0.16 |
| Former | 1272 (33.7) | 362 (31.4) | |
| Current | 201 (5.3) | 53 (4.6) | |
| Medical history | | | |
| Myocardial infarction | 212 (5.7) | 26 (2.3) | <0.001 |
| Coronary surgery | 83 (2.2) | 10 (0.9) | 0.004 |
| Angioplasty | 65 (1.7) | 9 (0.8) | 0.021 |
| Angina pectoris | 362 (9.8) | 59 (5.2) | <0.001 |
| Systolic blood pressure | 151.3 ± 23.3 | 146.2 ± 22.0 | <0.001 |
| Diastolic blood pressure | 83.9 ± 11.9 | 84.5 ± 11.1 | 0.05 |
| Systemic hypertension | 2586 (68.5) | 608 (52.7) | <0.001 |
| Stroke | 226 (6.1) | 37 (3.3) | <0.001 |
| Falls | 746 (19.8) | 181 (15.7) | 0.002 |
| Lipids | | | |
| Total cholesterol | 5.82 ± 0.99 | 5.80 ± 0.95 | 0.73 |
| LDL cholesterol (mmol/l) | 3.63 ± 0.86 | 3.6 ± 0.83 | 0.44 |
| HDL cholesterol (mmol/l) | 1.62 ± 0.41 | 1.66 ± 0.40 | 0.001 |
| Triglycerides (mmol/l) | 1.26 ± 0.63 | 1.18 ± 0.52 | <0.001 |
| Lipid-lowering agent | 1192 (31.6) | 368 (31.9) | 0.82 |
| Diabetes | | | |
| Self-declared | 329 (8.8) | 57 (5.0) | <0.001 |
| Fasting blood glucose | | | <0.001 |
| Blood glucose <6.1 mmol/l | 2961 (84.9) | 1042 (91.4) | |
| Blood glucose 6.1–7 mmol/l | 134 (3.8) | 30 (2.6) | |
| Blood glucose > 7 mmol/l | 391 (11.2) | 68 (6.0) | |
| CESD | | | |
| Non-depressive | 3119 (84.1) | 1022 (89.7) | <0.001 |
| Depressive | 588 (15.9) | 117 (10.3) | |
| Score | 9.0 [4.0;16.0] | 7.00 [3.0;13.0] | <0.001 |
| IADL | | | |
| Non-dependent | 3222 (86.0) | 1116 (97.8) | <0.001 |
| Dependent | 525 (14.0) | 25 (2.2) | |

Values are given as mean ± SD or median [interquartile range] for continuous variables and number (percentage) for categorical variables. CESD, Centre for Epidemiologic Studies Depression Scale; IADL, Lawton Instrumental Activities of Daily Living Scale.

body (Pathai et al. 2013). For instance, the eye has been cited as the mirror of the heart (Duprez 2007). Indeed, several age-related eye diseases such as open-angle glaucoma or AMD are associated with increased mortality and particularly mortality related to cardiovascular disease and stroke (Tan et al. 2008; Wu et al. 2008). Such

findings have also been observed for visual acuity as worse visual acuity and visual impairment were associated with an increased risk of mortality (Foong et al. 2008).

Disability can result from many causes such as stroke, dementia or cardiovascular diseases. In the elderly, one of the most severe causes of

disability leading to increased dependency is severe visual loss. It can directly impact daily life activities with increased falling and limitations for driving (Haymes et al. 2007). It has been found that in Western countries the leading cause of moderate and severe visual impairment was uncorrected refractive error followed by

Table 2. Self-reported history of eye diseases and ocular procedures among the participants of the Montrachet study.

| | Participants (<i>n</i> = 1153) | Onset (years) |
|--|---------------------------------|---------------|
| Self-reported history of eye disease | | |
| Age-related macular degeneration | 68 (5.9) | 4.5 ± 4.2 |
| Diabetic retinopathy | 9 (0.8) | 4.3 ± 4.9 |
| Ocular hypertension or glaucoma | 129 (11.2) | 10.3 ± 9.2 |
| Dry eye | 204 (17.7) | 5.1 ± 7.5 |
| Self-reported history of ocular procedures | | |
| Cataract extraction | 564 (48.9) | 6.4 ± 5.8 |
| Laser treatment* | 181 (15.7) | 8.2 ± 8.3 |

Values are given as number (percentage).

* The main indications for laser treatment were diabetic retinopathy, glaucoma, posterior capsule opacification after cataract surgery and age-related macular degeneration.

Table 3. Visual acuity in the better-seeing eye. The Montrachet study.

| | PVA < 20/60 | BCVA < 20/60 | PVA < 20/40 | BCVA < 20/40 |
|--------------------|-------------|--------------|-------------|--------------|
| All | 27 (2.3) | 21 (1.8) | 100 (8.7) | 45 (3.9) |
| 95% CI | 1.5–3.2 | 1.1–2.6 | | |
| Men | 11 (2.6) | 7 (1.6) | 32 (7.4) | 14 (3.3) |
| Women | 16 (2.2) | 14 (2.0) | 68 (9.4) | 31 (4.3) |
| 75–79 years | 6 (1.5) | 3 (0.8) | 21 (5.3) | 5 (1.3) |
| 80–84 years | 6 (1.2) | 4 (0.8) | 39 (8.0) | 17 (3.5) |
| 85 years and older | 15 (5.6) | 14 (5.3) | 40 (14.9) | 23 (8.7) |
| p-value* | 0.0003 | <0.0001 | <0.0001 | <0.0001 |

Values are given as number (percentage).

* Difference between age categories (chi-square test for trend).

PVA, presenting visual acuity (*n* = 1151); BCVA, best-corrected visual acuity (*n* = 1146).

Table 4. Crude prevalence of refractive errors by sex and age according to lens status in the Montrachet study (right eyes, *n* = 1133).

| Lens status | Pseudophakic | Phakic | p-value |
|-----------------------------------|--------------|------------|---------|
| Emmetropia, <i>n</i> = 318 (28.1) | | | |
| All | 202 (63.5) | 116 (36.5) | <0.0001 |
| Men | 59 (29.2) | 58 (50.0) | 0.0002 |
| Women | 143 (70.8) | 58 (50.0) | |
| 75–79 years | 56 (27.7) | 46 (39.7) | |
| 80–84 years | 79 (39.1) | 52 (44.8) | |
| 85 years and older | 67 (33.2) | 18 (15.5) | |
| p-value* | 0.61 | 0.22 | |
| Myopia, <i>n</i> = 387 (34.1) | | | |
| All | 231 (59.7) | 156 (40.3) | <0.0001 |
| Men | 79 (34.2) | 71 (45.5) | 0.025 |
| Women | 152 (65.8) | 85 (54.5) | |
| 75–79 years | 52 (22.5) | 63 (40.4) | |
| 80–84 years | 95 (41.1) | 63 (40.4) | |
| 85 years and older | 84 (36.4) | 30 (19.2) | |
| p-value* | 0.09 | 0.24 | |
| Hyperopia, <i>n</i> = 428 (37.8) | | | |
| All | 68 (15.9) | 360 (84.1) | <0.0001 |
| Men | 21 (30.9) | 137 (38.1) | 0.26 |
| Women | 47 (69.1) | 223 (61.9) | |
| 75–79 years | 20 (29.4) | 155 (43.0) | |
| 80–84 years | 33 (48.5) | 159 (44.2) | |
| 85 years and older | 15 (22.1) | 46 (12.8) | |
| p-value* | 0.08 | 0.16 | |

Values are given as number (percentage).

* Difference between age categories (chi-square test for trend).

cataract, AMD, glaucoma and diabetic retinopathy (Bourne et al. 2014). In the present study, presenting visual acuity and corrected visual acuity were not statistically different, which probably resulted from the good ophthalmological follow-up of this population. The prevalence of visual impairment in our elderly population was low in spite of the increased prevalence of age-related eye diseases. Perhaps the urban nature of the Montrachet population has led to good access to an ophthalmologist as the last visit was <2 years on average; it could be hypothesized that appropriate screening and management of eye diseases has been provided to this specific population. This is in accordance with the literature showing that the frequency of visits to an ophthalmologist was increased in the elderly (Levkovitch-Verbin et al. 2014).

In the Tromsø Eye Study, people older than 80 with visual acuity <20/60 in the better eye accounted for 7.8% of the males and 7.1% of the females. However, that age category represented only 333 of 6566 participants. In the EPIC-Norfolk Eye Study, the prevalence of moderate to severe impairment and blindness (VA <6/18 in the better eye) was 0.74% (Khawaja et al. 2013). The mean age of these patients with low vision and blindness was higher than in people with no visual impairment, 75.8 versus 68.6 years, respectively. In the Pola Study, a French population-based study targeting individuals 63 years and older, moderate to severe visual impairment (i.e. visual acuity < 20/70 in both eyes) was found in 7.5% of the cohort (Daien et al. 2014).

Refractive errors found in the Montrachet Study are in accordance with the recent literature in Caucasians, although some cut-off points may be slightly different. We found a high prevalence of astigmatism as previously described in older persons (Williams et al. 2015). We also observed a decrease of SE with age regardless of the lens status. In phakic participants, this could be related to the decrease in the prevalence of hyperopia after 75 years (Williams et al. 2015) while in pseudophakic participants, we could hypothesize that cataract surgeons were aiming a negative spherical equivalent to favour near vision in older persons.

Although cataract surgery may modify the refractive status, we considered also pseudophakic eyes to report global refractive errors in a real-world situation because these eyes represented about half of our population (49.4%). This rate is much higher than in population-based studies undertaken in the 1990s. For instance, the rate of cataract extraction was 10.6% in the Beaver Dam Study and 23.7% in the Salisbury Eye Evaluation Project for white women over 65 years of age (Klein et al. 1994; Rubin et al. 1997). In addition, the Alienor Study reported similar results to ours with a rate of cataract extraction up to 37.1% in men and 50.2% in women (Delcourt et al. 2010). The main reason is probably the older age of the participants in these two French population-based studies focusing on the elderly as well as the changes in cataract extraction indications over the last two decades. In 1993, the number of cataract extractions was 247 300 in France, while it rose to 667 365 in 2010 (Atih, <http://www.atih.sante.fr/statistiques-utilisation-des-codes-diagnostics-principaux-ou-actes-classants-dans-les-bases>: accessed on May 20, 2015). This has to be taken into consideration because lens status may impact ocular variables such as IOP or macular pigment optical density measurements (Shrivastava & Singh 2010; Sasamoto et al. 2011).

Finally, these old people represent only a small percentage of individuals included in normative database of imaging devices used in clinical practice in ophthalmology. Therefore, population-based studies focusing on the elderly such as the Alienor and the Montrachet studies give a unique opportunity to contribute valid information in this targeted age range. As ageing impacts measurements obtained with optical coherence tomography devices, there is probably a need to better define the normal range of this old population with a larger sample (Patel et al. 2014).

We acknowledge several limitations to this study. First, the approximately 50% participation rate was not optimal. This is mainly due to the age of our population ranging from 75 to 96 years. In the Salisbury Eye Study in which the participants ranged from 65 to 84 years of age, the participation rate was 66%, much lower than in

population-based studies involving younger individuals (Rubin et al. 1997). Indeed, older people are more reluctant to attend a medical examination for many reasons such as transportation and availability of caregivers (Keeffe et al. 2009). Thus, the prevalence of visual impairment may be underestimated because it can be expected that people with low vision or blindness are even more reluctant to participate. However, if participants with an MRI are considered, the participation rate was better. Second, we did not visit the participants in nursing homes, as was performed in other studies (Wolfs et al. 2000). Third, this study only deals with a white and urban population; therefore, the results cannot be extrapolated to other groups. Fourth, due to the relatively small sample, eye diseases with a low prevalence will reach a small number of cases, and therefore, this weakens the conclusions that can be drawn. However, pooling our data with the Alienor Study, which shared the same design, will provide more robust findings. Fifth, the evaluation of visual impairment was limited to visual acuity. Other studies have harvested visual function impairment more in depth with other tests such as contrast sensitivity, glare and stereoacuity (Rubin et al. 1997).

In conclusion, the Montrachet study is a good opportunity to describe the pattern of eye diseases in an elderly French urban population. Its design will help to decipher associations with systemic diseases (mainly cardiovascular and neurologic) and could help to better concentrate healthcare resources on targeted subgroups.

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