

# Cost-effectiveness of the triple procedure – phacovitrectomy with posterior capsulotomy compared to phacovitrectomy and sequential procedures

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## ABSTRACT.

**Purpose:** To evaluate the cost-effectiveness of the triple procedure (phacovitrectomy + posterior capsulotomy, PhacoPPVc) compared to the double- (phacovitrectomy, PhacoPPV) or single sequential procedures.

**Methods:** Prospective study on 31 eyes from 31 patients (mean age: 72.1 ± 9.1 years; 55% females) was performed with a preoperative decision to undergo only *pars plana vitrectomy* (PPV) (26%) or PhacoPPV (74%) and/or posterior capsulotomy based upon presence or absence of lens opacification or pseudophakia. Time during and between surgeries, surgical procedure codes, medical and transport costs, outcome and likelihood of complications after surgery were all included in the analysis. Societal perspectives and visual acuity were considered as measures of quality of adjusted life years (QALYs).

**Results:** About 23 eyes underwent triple procedure and eight eyes underwent vitrectomy only (mean surgery times: 35.9 and 24.0 min, respectively). Posterior capsulotomy took on average 30 s, while preparation and cataract procedure took 13.0 min. The patients travelled on average 80km (average cost: \$280.12) to the surgery unit. The average reimbursement fee for the day procedures ranged between \$174.17 (YAG capsulotomy; Diagnosis Related Group (DRG): 0.034), \$1045.48 (Phaco + intraocular lens (IOL); DRG: 0.204) and \$1701.32 (PPV; DRG: 0.332). The combined procedures excluded lens and laser reimbursements, while the calculated reimbursements for the double/triple procedures were \$2713.08/\$2901.45, respectively, without significant loss of QALYs. PhacoPPVc was found to be unequivocally cost-effective, while PhacoPPV remained cost saving compared to sequential procedures.

**Conclusion:** This study confirms that the triple procedure has benefits to the patients, health institution and surgeon. For patients, it saves them travel and healing time; for health institution, it justifies the calculated higher costs and need for higher reimbursement for the double/triple procedures, which are cost saving.

**Key words:** combined surgery – cost-effectiveness – diagnosis related group – double and triple procedure – phacovitrectomy – posterior capsulotomy – vitrectomy

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## Introduction

*Pars plana vitrectomy* (PPV) is currently the mainstay treatment for vitreoretinal disorders requiring surgery. Initially, this procedure included removal of the lens that permitted better anterior vitreous examination, which later became altered by lens preserving procedures, such as inclusion of glucose in the surgical infusion line to reduce intraoperative lens opacification (Lahey et al. 2003). The controversial aspect of treating cataract in patients undergoing vitrectomy soon became solved by the increasing practice of surgeons performing combined surgery, in particular, risky patients. Phacovitrectomy (phacoemulsification + intraocular lens (IOL) implantation + PPV or PhacoPPV) is now considered a reliable, safe and cost-saving procedure, for the price of insignificant surgical time increase (Tornambe et al. 1997; Simcock et al. 2000; Lahey et al. 2003; Pearce 2004; Sisk & Murray 2010; Moon et al. 2015). *Pars plana vitrectomy* (PPV) in itself is a risk factor for developing cataract by altering the oxygen concentration in the eye. To eliminate increased morbidity in patients, combined PhacoPPV should thus be considered (Simcock et al. 2000; Lahey et al. 2002; Jackson et al. 2013a,b,c; Moon et al. 2015).

Eminent benefits of PhacoPPV include greater accessibility to the vitreous base, improved posterior segment visualization, speedy patient recovery and avoidance of multiple

surgical procedures, as well as costs related to ophthalmological and surgical visits (Demetriades et al. 2003; Lahey et al. 2003; Sisk & Murray 2010; Jackson et al. 2013a,b,c). Despite these benefits, PhacoPPV may lead to an unwanted increased rate of posterior capsular opacification (PCO), which is otherwise common after cataract surgery, as well as corneal oedema, retinal detachment and higher intraocular pressure (Hurley & Barry 1996; McElvanney & Talbot 1997; Scharwey et al. 1999; Lahey et al. 2002; Demetriades et al. 2003; Villegas et al. 2014). Therefore, surgeons may choose to do a triple procedure (PhacoPPV + posterior capsulotomy or PhacoPPVc) to prevent patient morbidity and the additional YAG laser capsulotomy at a later point, with the purpose to assure long-standing improved visual acuity (VA) during one surgery setting (Lahey et al. 2003).

As PhacoPPV and PhacoPPVc continue to gain popularity, less is known about the cost-effectiveness of the procedures. Some studies have assessed PhacoPPVc intervention effects without considering the costs attached. The cost assessment has received less attention, since PhacoPPVc is not a well-established intervention in ophthalmological treatment, and hence lacks optimization of cost weights, which require revision. Very few studies have assessed the cost-effectiveness of the double procedure, with findings including the cost-saving aspect for the health institution, healthcare system and the patients (Seider et al. 2014; Rufai et al. 2017). One previous study has argued that the reduced costs with the double procedure are related to the single surgeon, the reimbursed fees on Ambulatory Surgical Centre as well as the fee for anaesthesiology applied (Seider et al. 2014).

In the present study, we evaluate the cost-effectiveness of combined double (PhacoPPV) and triple (PhacoPPVc) procedures in comparison to individual surgical treatments. A societal perspective of a 2-year time horizon was deemed sufficient to capture all costs and effects associated to the treatment options. This is the first study to evaluate the cost-effectiveness for the three surgical treatments combined.

## Methods

This prospective study was carried at the Department of Ophthalmology, Oslo University Hospital (OUH). All eye examinations were performed prior to surgery, when a decision to undergo only PPV (26% of the cases) or PhacoPPV (74% of the cases), and/or capsulotomy was made upon presence or absence of lens opacification (cataract) or pseudophakia by a single surgeon (G.P). Only cases with maculopathies and no previously known surgery or complication such as retinal detachment or vitreous haemorrhage were included.

Surgeries were performed under retrobulbar anaesthesia. Phacoemulsification involved implantation of an acrylic foldable IOL in the capsular bag. A PPV with 25-gauge, standard 3-port approach was done in each case. Central core vitrectomy was performed followed by detachment of the posterior hyaloid. The peripheral vitreous was then removed with careful inspection of the retinal periphery. After surgery, combined topical steroids and antibiotics (Maxitrol®, Novartis, Basel, Switzerland) three times daily for 3 weeks and cycloplegics (Cyclopentolate® 1%; Bausch Health, Laval, Quebec, Canada) two times daily for 10 days were prescribed.

The time during surgery was recorded from the patient arrival to the surgery room until the end of the surgery; each sub-procedure time was also recorded separately.

### Cost calculation

Direct medical as well as non-medical costs were included in the study, such as medications/drugs used during surgery, patient transport costs to the examining clinics/hospital, as well as medical costs incurred at the local clinics and the surgical unit. The pre-operative check-up cost at OUH was assumed to be covered in resource utilization cost in the specific surgery category and above that all patients underwent similar procedure. Indirect medical costs related to the subjects' work productivity were excluded from this study, as the population involved was beyond working age, except for two subjects who were <60 years. All procedures included in the study were day surgeries. With the recorded

location of patients, distance was calculated and cost per km information was derived from the Statistics Norway for year 2017, to estimate the patient transport costs. Medical costs for attending the local eye clinics were also collected, together with the information on treatment costs in various areas of the country and their practices for year 2018. To estimate the cost of treatment at OUH, the third-party payments were used. Thus, surgical procedure codes were recorded on diagnostic related group (DRG) weights, which could determine the reimbursement fee. The individual procedure fees (Cataract surgery, PPV and Posterior capsulotomy) covered 50% of the cost and were essentially used to calculate the resource utilization of the associated surgery (Yin 1993). The resource utilization of PhacoPPV and/or posterior capsulotomy (triple procedure) was determined by a formula as the procedures were reimbursed at a fee of vitrectomy, while PhacoPPVc was totally new in the system.

Nevertheless, to avoid biasness on the cost as suggested by Yin & Forman (1995) as well as Drummond et al. (2015), it was worth formulating an associated viable cost in relation to time consumed and the combined procedures while maintaining the same payment-to-cost ratio as shown below:

$$\text{PhacoPPV} = \frac{C_r + V_r}{\text{PhacoPPV}_t}$$

$$\text{PhacoPPVc} = \frac{C_r + V_r + P_r}{\text{PhacoPPVc}_t}$$

$C_r$ , cataract reimbursement;  $V_r$ , PPV reimbursement;  $P_r$ , posterior capsulotomy reimbursement.  $\text{PhacoPPV}_t$  and  $\text{PhacoPPVc}_t$  denote the average time taken for combined surgeries, without or with, capsulotomy, respectively.

The results of the formulas above were considered as possible reimbursements for combined surgery, and payment-to-cost ratio was applied to estimate the resource utilization cost. All cost values were converted to U.S dollars (\$) in accordance with an international exchange rate on 13 November 2018 (1 NOK = \$0.118).

### Outcomes

Each procedure's effective measure was evaluated based upon the VA

associated to a successful surgical process. This study was undertaken from June to October 2018 and could not take into account the long-term post-operative follow-ups to record directly the resulting VA of the studied subjects, since OUH is a tertiary care department, which refers back the postsurgical cases to their local outpatient ophthalmology clinics (OOCs). As this is one of the recognized challenges of cost-effectiveness analysis studies, several authors suggest the systematic use of appropriate data from various clinical studies instead (Sutton & Abrams 2001; Ades et al. 2006; Briggs et al. 2006). Accordingly, the VA data were based upon previously published results from random clinical trials and systematic reviews in which the likelihood of complications after a given surgery was also recorded. In addition, a statistical approach was taken to link the quality of adjusted life years (QALYs) to the VA outcome data.

#### Discounting analysis

The cost and outcome in the model were in favour of the same discount rate at 3% as suggested by WHO, considering that the utility achieved at the time of treatment was more valuable than the disutility patients were to undergo to achieve further utility in the future of the 2-year time horizon.

#### Analysis model

A decision tree was developed as a tool for the comparative analysis on the cost and outcomes of the studied subjects (Fig. 1). This was considered the appropriate tool in this study due to the short time horizon as well as the number of events of the strategies with almost immediate outcome. The model also provides appropriate insight applicable to the clinical problem of this study (Barton et al. 2004; Cooper et al. 2007; Roberts et al. 2012; Siebert et al. 2012). Similarly, not all the intervention procedures could fulfil the Markov assumption, thus the Markov model was considered not to fit the characters and the structural requirements (Sonnenberg & Beck 1993; Det-sky et al. 1997; Naimark et al. 1997; Roberts et al. 2012; Siebert et al. 2012). MS Excel software was used in the analysis as well as STATA 15 (Stata version 15.0; College Station, TX,

USA) for the descriptive statistics. The model was based on the ophthalmological treatments in which either the patients received sequential surgical treatment, given the probability of the advanced effect as a consequence of a prior treatment or a combined treatment to eradicate additional care. The model thus specifies a decision tree of whether the patients are given either of the following options: sequential procedures PPV, phacoemulsification, followed by posterior capsulotomy, PhacoPPV followed by posterior capsulotomy or PhacoPPVc as a triple procedure at a given time and on a particular patient.

For patients undergoing PPV, the literature-based probability of developing cataract in 6 months was 81%, while at 1 year it was an additional 17%, and by 2 years a cumulative 100% (Cheng et al. 2001; Jackson et al. 2017; Table S1). Upon cataract surgery 76% of the patients experienced improved VA with QALYs of 0.82, while 24% had a probability of postcataract risk for developing secondary cataract (PCO) within a year. Consequently, upon YAG laser capsulotomy, almost 87% had a chance of improved VA with QALY of 0.85 or 13% had a chance of worse VA with QALY of 0.73 (Brown et al. 2001; Busbee et al. 2003; Roh et al. 2009). Those undergoing PhacoPPV could either get an improved VA (89%), QALYs of 0.8 or still stand a risk of a secondary cataract (11%), hence subjected to YAG laser; 0.87 receive a better VA with QALYs of 0.79 or otherwise 0.13 worse VA with QALYs of 0.73 (Fajgenbaum et al. 2018). The intervention with the triple procedure, based upon literature, showed a probability for getting better VA in 99% of cases with QALYs of 0.92, while 1% experienced QALYs of 0.83 (Brown 2000; Brown et al. 2001; Aizawa et al. 2012).

Patients in the Norwegian healthcare system seek eye care initially from private OOCs, which have agreements with the state health fund, and then get referred to the tertiary care centres, such as OUH, for vitrectomy. OUH is the only surgical retina centre for the whole South-Eastern Health region of Norway, with a population of approximately 2.5 million people. At the surgical clinic, the patients are examined and later given appointments for

surgery; after surgery, the first control examination is carried out at the surgery site, while the further controls are carried out at the referring private OOCs. This was included in the model as the frequency of either going to a private OOC for a given condition or the number of travels to the surgical unit.

The probability path of each decision option was calculated together with the associated costs of each option, and then, the expected QALYs or costs were estimated as the product of the path probability and the option related QALYs or costs. The incremental cost-effective ratios (ICER) were calculated by dividing expected cost with expected QALY of the linked option. The model used a 2-year time limit as almost all patient's effects to treatment strategies employed in the study could have been realized (Cheng et al. 2001; Jackson et al. 2017). A societal perspective was also considered for this model's cost calculation.

#### Sensitivity analysis

One-way and two-way sensitivity analyses were used to assess the robustness of the model in relation to the parameters that were considered uncertain. This included time used for doing surgery, calculated cost of combined surgeries and the discount rates.

In addition, a probabilistic sensitivity analysis (PSA) was included to test uncertainty, especially on the secondary data parameters used, and to capture any interaction on all the parameters within the model (Baltussen et al. 2002). On probability values with unreported standard deviation and cost based on DRG, a standard error of 20% was assumed.

## Results

The descriptive data on the studied subjects and the procedures performed are shown in Table 1. Thirty-one eyes from 31 patients (mean age:  $72.1 \pm 9.1$  years; 45:55% males:females) were included in the study. Twenty-three eyes underwent the triple procedure/PhacoPPVc (mean surgery time: 36.9 min), while eight eyes underwent PPV only (mean surgery time: 24.4 min). Posterior capsulotomy took on average 0.5 min, while the preparation with the cataract procedure itself took (mean surgery time:

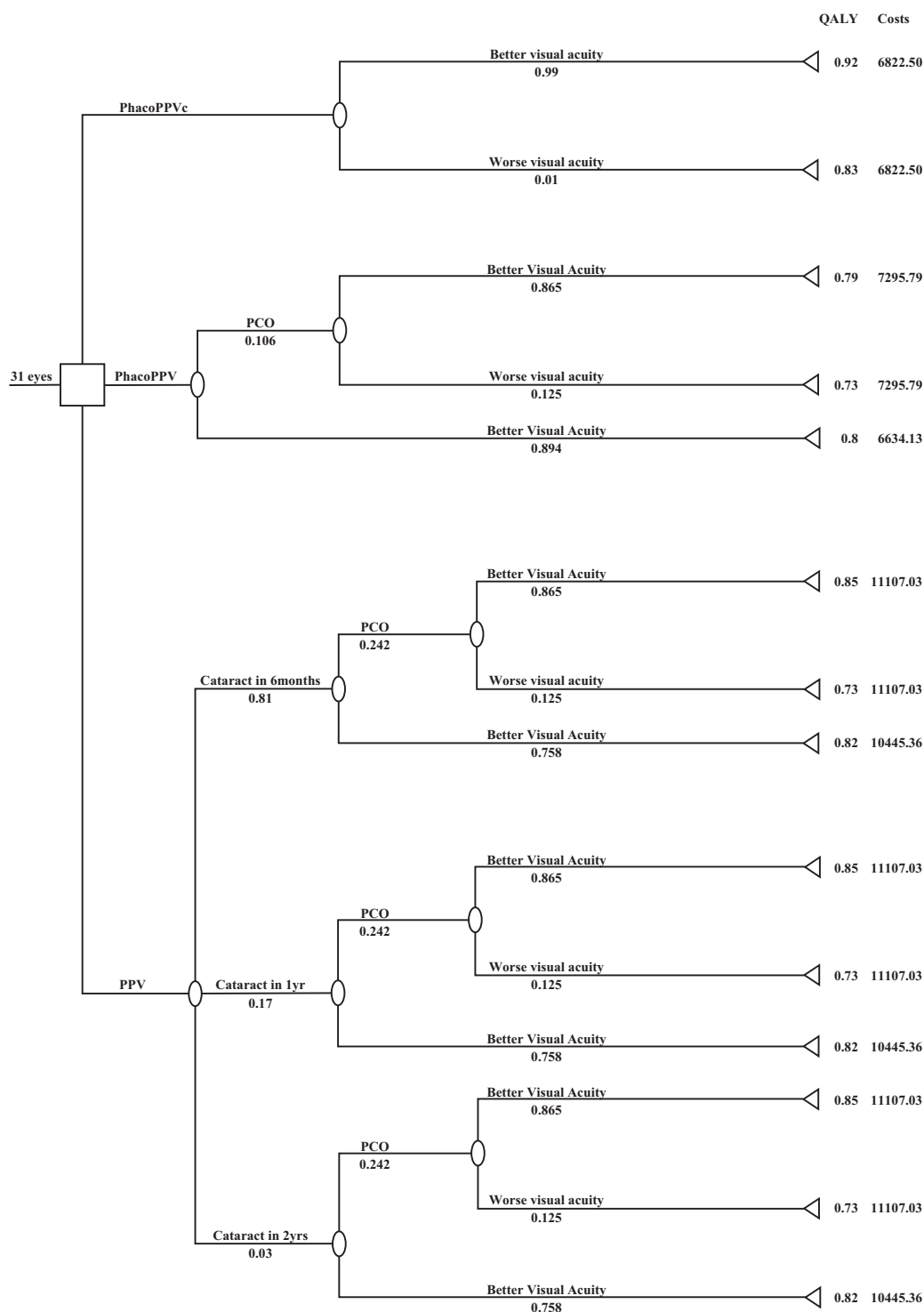


Fig. 1. Decision tree model.

13 min). On average, the patients travelled 79.9 km (range: 1.6–223 km) to the surgery unit (OUH) with an average travel cost of \$280.12, while they travelled 29.6 km (range: 0.7–202 km) to the OOC at an average cost of \$103.69.

Distance travelled by patients to OOC or OUH is indicated in Fig. 2A, while the

regional distribution or the patient density of the referrals is shown in Fig. 2B, with at least one patient having travelled as much as 223 km for surgery.

The average reimbursement for the single procedures studied were as follows: \$87.08 (YAG laser capsulotomy; DRG: 0.034), \$522.74 (phacoemulsification + IOL implantation; DRG:

0.204) and \$850.66 (PPV; DRG: 0.332), all being weighted out as outpatient procedures according to the DRGs. Using the formulas shown in the Methods section, the calculated new reimbursement fee for PhacoPPV was determined to be \$1356.54 and for PhacoPPVc to be \$1450.73 (Table 2). The reimbursement fee per minute of



**Table 1.** Descriptive data on the age of the patients, distance travelled/cost and surgical time.

	<i>n</i>	Mean	SD	Minimum	Maximum
Age (years)	31	72.06	9.10	48	91
Distance to OOC (km)	31	29.59	40.20	0.70	202
Distance to OUH (km)	31	79.93	66.84	1.60	223
Travel cost (\$) to OOC	31	103.69	140.89	2.45	707.93
Travel cost (\$) to OUH	31	280.12	234.23	5.61	781.53
PPV (min)	8	24.39	4.81	19.15	34.24
Phacoemulsification + IOL (min)	23	12.98	1.61	9.83	16.65
Posterior capsulotomy (min)	29	0.48	0.13	0.28	0.83
PhacoPPV (min)*	23	36.23	5.44	29.54	51.61
PhacoPPVc (min)	23	36.91	5.45	29.95	52.28

IOL = intraocular lens, OCCs = outpatient ophthalmology clinics, OUH = Oslo University Hospital, PPV = Pars plana vitrectomy.

\* PPV time represents outpatient surgery for otherwise uncomplicated maculopathies, such as epiretinal fibrosis or macular hole surgery.

the combined PhacoPPV and PhacoPPVc were \$37.44 and \$39.30, respectively.

Resource utilization for all procedures was therefore a product of the reimbursement fee multiplied by two, as the reimbursement fee represented 50% of the accounted cost.

#### Expected costs and incremental cost-effective ratios

The weighted probability-associated surgical cost of the sequential and combined (double and triple procedures) and the associated QALYs are shown in Table 3. The sequential procedures lead to a higher average

societal cost (\$10 405.39) and a relatively higher outcome (Expected QALYs: 0.830). The combined procedures – double or PhacoPPV, had societal average cost of \$6674.229 (Expected QALYs: 0.797), while the triple or PhacoPPVc procedure had on average a slightly higher cost than the double procedure (\$6822.501), but also a slightly higher outcome (Expected QALYs: 0.919).

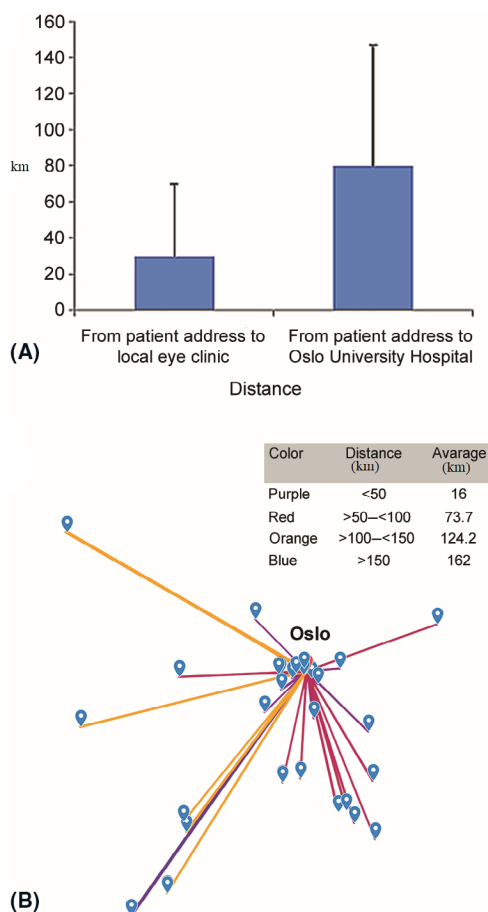
The findings of the ICER analysis indicate a cost saving of \$3731 and \$3583 per patient for the double or PhacoPPV and the triple or PhacoPPVc procedure, respectively, compared to the single sequential procedures (Table 4, upper and lower panels). When comparing the two combined procedures, it appears to be an incremental cost of \$148 for an increase in QALYs by 0.12 (middle panel). Thus, the triple or PhacoPPVc procedure is unequivocally cost-effective in comparison to the sequential procedures – it has a low incremental cost \$3583 and higher QALYs of 0.11, while compared to the double procedure it leads to an ICER of \$1194 per QALY.

The cost-utility plane with relative point estimates of the incremental cost and QALYs are shown in Fig. 3, with point A being the comparison between PhacoPPV or double procedure and the sequential surgery – it indicates reduced cost and reduced QALYs for the former; point B represents the comparison between PhacoPPVc and PhacoPPV, showing slightly higher cost and substantially increased QALYs for the triple procedure; point C compares the PhacoPPVc to the sequential procedures, indicating very low cost associated with the triple procedure.

#### Sensitivity analysis

The surgical time used for the combined procedures indicated higher negative incremental cost with less time used for the surgery and only turns into a positive incremental cost after 86 and 82 min for PhacoPPV and PhacoPPVc, respectively (Fig. 4).

To further test the sensitivity of the results obtained, an additional cost of 10–20% for the PhacoPPV and PhacoPPVc was applied. The percentage values were used to relatively reflect the U.S. Medicare system, which reimburses 50% of the second treatment



**Fig. 2.** Distances travelled by the patients to the outpatient ophthalmology clinics (OOCs) and the tertiary care centre at Oslo University Hospital (OUH).

**Table 2.** Reimbursement for different surgical procedures in ophthalmology with the associated cost.

Procedure (day surgery)	Reimbursement (\$)	Reimbursement per min (\$)	Resource utilization cost (RUC) \$	Adjusted RUC for different countries*							
				RUC Coeff <sup>†</sup> Norway <sup>†</sup> (65 599)	USA (62 641)	UK (45 489)	Australia (51 602)	Canada (48 107)	China (18 210)	Brazil (16 068)	South Africa (13 730)
Phacoemulsification + IOL	522.74	40.27	1045.48	0.0159	998.34	724.98	822.40	766.70	290.22	256.08	218.82
PPV	850.66	35.89	1701.32	0.0259	1624.60	1179.76	1338.31	1247.66	472.28	416.73	356.09
Posterior capsulotomy	87.08	182.17	174.17	0.0027	166.32	120.78	137.01	127.73	48.35	42.66	36.45
Calculated reimbursement rate for combined procedures											
PhacoPPV	1356.54	37.44	2713.08	0.0414	2590.74	1881.36	2134.18	1989.64	753.14	664.55	567.85
PhacoPPVc	1450.73	39.3	2901.45	0.0442	2770.62	2011.98	2282.36	2127.78	805.43	710.69	607.28

IOL = intraocular lens, PPV = Pars plana vitrectomy.

GDP-PPP data extracted from World Bank indicators for 2018.

\* Adjusted for each country's known GDP-PPP.

† Adjusted for GDP-PPP for the RUC values.

**Table 3.** The weighted probability-associated surgical cost and quality of adjusted life years (QALYs).

Procedure type	Expected cost (\$)	Expected QALY
Sequential procedures	10 405.39	0.830
PhacoPPV	6674.23	0.797
PhacoPPVc	6822.50	0.919

in combined procedures. The cost for the double procedure appears to be sensitive at lower costs of PhacoPPVc, with associated negative ICERs. This indicates that the PhacoPPVc is probable to remain cost saving for various cost points. However, with lower costs for PhacoPPV and higher costs for PhacoPPVc, one obtains positive ICERs for various costs points (Fig. 5).

#### Discount rates sensitivity

The discount rates (0–5%) were tested on the QALYs and cost in relation to the model ICERs (Table S2). The higher QALY discount rates (4–5%) tended to increase the ICER values of the combined procedures compared to the sequential procedures for all cost discounts (0–5%), except at 4% for PhacoPPVc versus Sequential model at a 0% cost discount. Meanwhile, the higher cost discount (4–5%) increased the ICERs on all QALY discounts for the PhacoPPVc versus PhacoPPV model. At 3% cost discount, increased ICERs were observed for lower QALY discounts (0–2%).

#### Probabilistic sensitivity analysis

The effects of all the variables including those assessed in the deterministic analysis were tested in a probabilistic analysis. With scenarios of 1000 iterations, which included set standard error above 50%, PhacoPPVc remained being cost-effective. Nevertheless, the 20% variation in parameter mean scenario has been reported (Briggs et al. 2012; Caro et al. 2012).

Figures 6 and 8 show the PSA scatter plot of PhacoPPVc and PhacoPPV compared to sequential procedures, respectively. The results are based upon 1000 iterations and indicate cost saving of \$3534 (former) and \$3667 (later) per person in 2 years. Various thresholds that include higher value as \$88 500 indicate PhacoPPVc

**Table 4.** Results of the incremental cost-effectiveness ratios (ICERs) of the different surgical procedures performed in the study.

Strategy	Cost (\$)	QALY
Sequential surgeries	10 405	0.808
2-step combined surgery (PhacoPPV)	6674	0.795
Increment	–3731	–0.013
	ICER	\$280 936
2-step combined surgery (PhacoPPV)	6674	0.795
3-step combined surgery (PhacoPPVc)	6823	0.919
Increment	148	0.124
	ICER	\$1194
Sequential surgeries	10 405	0.808
3-step combined surgery (PhacoPPVc)	6823	0.919
Increment	–3583	0.111
	ICER	\$–32 307

QALY = quality of adjusted life years.

to be more than 85% cost-effective compared to sequential procedures (Fig. 7). Even though PhacoPPV is indicated to be 100% cost-effective from very low threshold up to \$5500, at higher threshold values as \$80 000, the probability of remaining cost-effective drops to 60% (Fig. 9).

## Discussion

The current study is to our knowledge the first to evaluate the cost-effectiveness of the triple procedure or PhacoPPVc and compare it to either the double- (PhacoPPV) or the single sequential procedures. The main finding is that PhacoPPVc is an unequivocally cost-effective procedure compared to the sequential procedures. In addition, the procedure is also cost-effective compared to the PhacoPPV procedure, even if the minimum cost threshold (\$32 450) was to be considered (Helse- og omsorgsdepartementet 2015). The

Norwegian Knowledge Center for Health Services compares ICER to the \$59 000 threshold regardless of the conditions gravity (Kåre et al. 2012). These data are in coherence with studies from the UK and the United States, which found the double procedure to be cost saving compared to the sequential procedures (Seider et al. 2014; Rufai et al. 2017). Unlike our study, which provides new information regarding the triple/PhacoPPVc procedure, the above studies provide no mention of the effects' size nor the incremental QALYs.

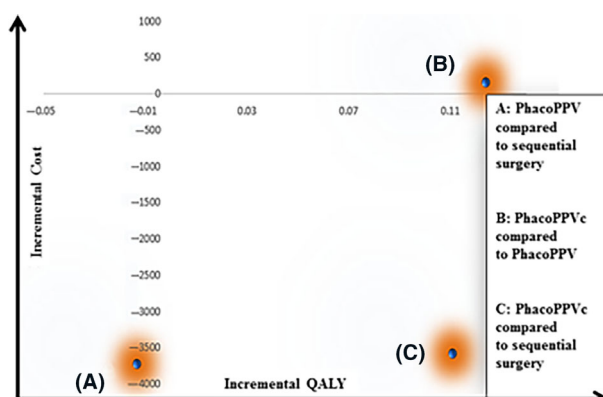
The cost-benefits of the double or the triple procedures is mostly considered a result of the reduced medical cost in relation to the one-time use of anaesthetic and other medicines during surgery, combined with the savings of the transportation costs, as the frequency to the surgical centres or the eye clinics get reduced. Rufai et al. (2017) and Seider et al. (2014) evaluated phacoPPV against the sequential

procedures, and we hereby strengthen and show in addition that the triple procedure has increased benefits.

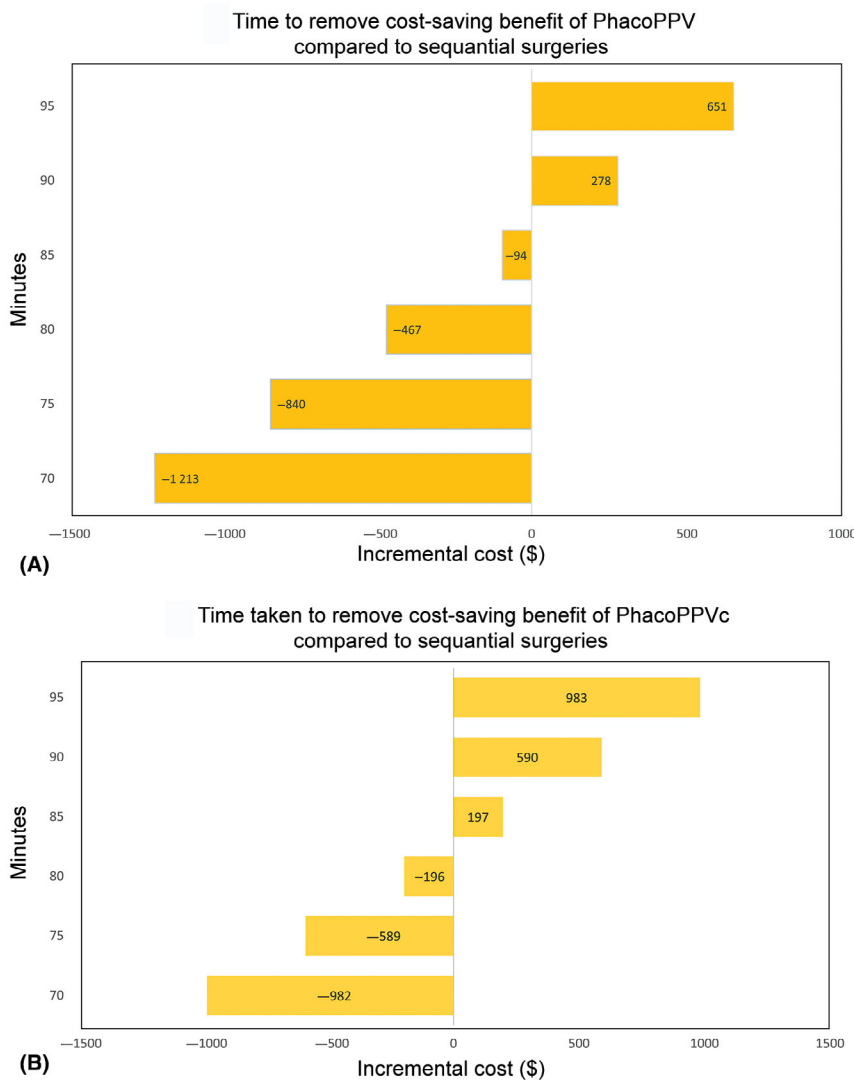
The present study also indicates relatively lower costs for the combined procedures, while the triple procedure stands out with potential higher patient benefits, over and above the reduced healing time, the number of visits and not to mention the psychological positive effect due to the treatment. As some patients travelled long distances and most patients in the study also were elderly with a mean age of 72 years, the combined procedures would be a tool to align with the National Health and Hospital Plan 2016–2019, which endeavours among others, to renew and simply to provide improved services and thus strengthen the quality and safety where patient demographics do not define treatment quality (Nasjonal helse- og sykehusplan 2016–2019).

Another aspect of the combined treatment in the economies of scale, even though the cost estimates were not included in this study, is the reduced time spent in the surgical theatre, thus providing facilities for more patients while reducing the waiting time for treatment. In addition, the healthcare workers get more time for other hospital activities. Furthermore, in a sensitivity analysis, these procedure benefits could perhaps be eliminated with an unlikely longer surgical time (PhacoPPV > 86 min and PhacoPPVc > 82 min). This is in line with a study from the UK; however, their time of surgery was much longer (>109 min) to eliminate the added benefit (Seider et al. 2014; Rufai et al. 2017).

Since there are no specific DRG codes to reimburse for the combined surgeries, this may lead to unintentional DRG consequences like skimping and failure for patients to receive quality benefits of the triple procedure, as the department or physicians may feel penalized for offering combined treatment, yet not being compensated (Mathauer & Wittenbecher 2012). As it is known that DRG is an effective way to enhance efficiency and may lead to moderate activity levels in treatment (Street et al. 1983; Januleviciute et al. 2011), implementing DRG codes where different treatments are combined into a single code could improve the incentives for a more cost-effective health care. This could avoid those who offer the combined surgeries, to exercise



**Fig. 3.** Cost-effectiveness plot for the different surgical procedures performed in the study and their comparison.



**Fig. 4.** One-way sensitivity analysis of the surgery time for the different procedures. (A) shows that PhacoPPV remains cost-saving even for longer surgeries of up to 86 min. (B) indicates the PhacoPPVc will lose its cost-saving benefit, if a surgery would take longer than 82 min.

patient selection or cost-shifting which undermines the efficiency, quality of care and equal treatment to all patients. In addition, among other studies, Januleviciute et al. (2011) evaluated the effect of DRG changes in response to patient treatment in Norway and the results indicate a positive change with an increase in DRG points. Even though their study could not significantly indicate the same behaviour on surgical or medical cases but only among emergencies, the case in our study would probably have a significant effect considering there is time saved by combining the treatments, thus eventually reducing the waiting time for other patients. This kind of response, however, clearly shows there exist elasticity in price changes which are due to DRG, while

considering other factors that can jiggle the hospital-fixed capacity. Hence, in keeping abreast with the new health and hospital plans adapting a DRG weight for combined treatments may result to improved quality of care, while more patients are able to receive treatment in a reduced waiting time.

However, like in the USA, Medicare is likely not to compensate for combined surgeries if there is no significant visual cataract in the vitrectomized eye (Seider et al. 2014). Importantly, it has been proved in many studies, there is a very high likelihood of developing cataract after vitrectomy, and in addition, within 2 years all patients have that risk (Simcock et al. 2000; Cheng et al. 2001; Lahey et al. 2002; Romero-Aroca et al. 2009; Sisk & Murray 2010; Jackson et al. 2013a,b,c; Villegas et al.

2014). Thus, to improve the quality of treatment would be to utilize treatment strategies that give higher patient benefits while reducing cost, and at the same time department providers are compensated accordingly.

The DRG systems are based on different national calculations reflecting the cost of treatment of a DRG classification by either the average cost of specific hospitals or all the national hospitals, in addition to other demographic factors or without (Januleviciute et al. 2011; Mihailovic et al. 2016). Yet, as new technologies emerge and new treatments are discovered, the costs fluctuate and the DRG weights attached to former treatments may become obsolete, thus new/updated DRG codes should be generated. In this study, we evaluate the cost-effectiveness of combined procedures and the findings for PhacoPPVc stand out to facilitate best patient treatment yet, with reduced cost. Furthermore, the sensitivity analysis indicates that it may take up to 20% increase of the calculated cost to experience higher ICERs per QALY in the model.

Depending on how often the system is revised, a more frequent appraisal within the hospital should be carried out to have a better estimate of the cost data (Januleviciute et al. 2011; Mathauer & Wittenbecher 2012). Thus, a system with constant adaptation of modification can certainly outweigh the complexities in health care institutions and adequately compensate providers (Scheller-Kreinsen et al. 2009; Mathauer & Wittenbecher 2012).

An efficient DRG system would need accurate input information recorded by the providers, while remaining as an incentive to competent care by the physician. Contrary to arguments of conflict of interest, the providers remain to be the critical element in ensuring the system is well utilized for cost containment (Mathauer & Wittenbecher 2012). Hence, providers' involvement from initiation throughout the procedural work and feedback on treatment needs or development can contribute to the system dynamism within certain constraints.

The suggestions by Januleviciute et al. (2011) are in line with ours regarding pursuit of effective behavioural drive within hospitals, meaning



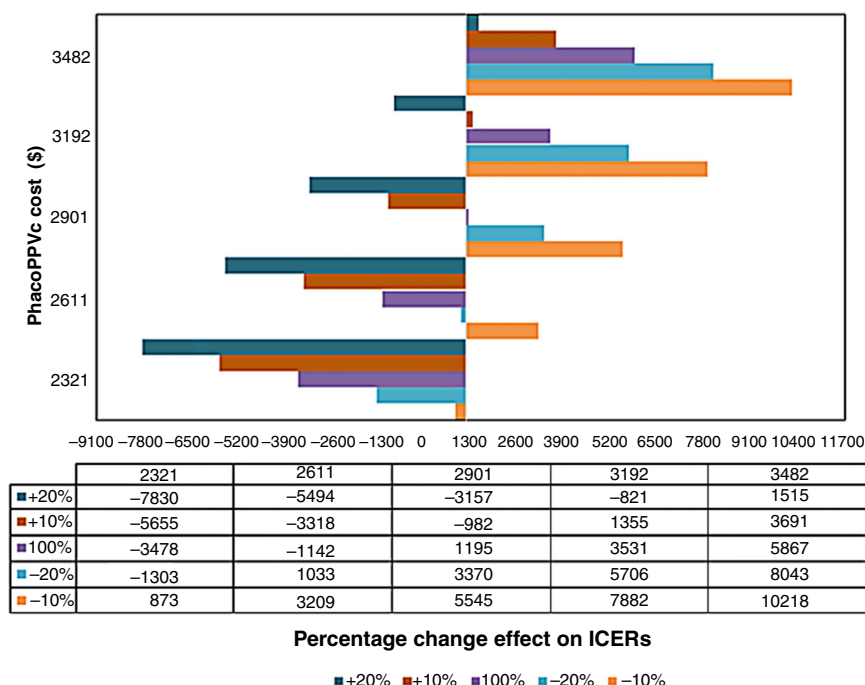


Fig. 5. Two-way sensitivity analysis on the calculated costs of PhacoPPVc and PhacoPPV upon the incremental cost-effective ratios (ICER).

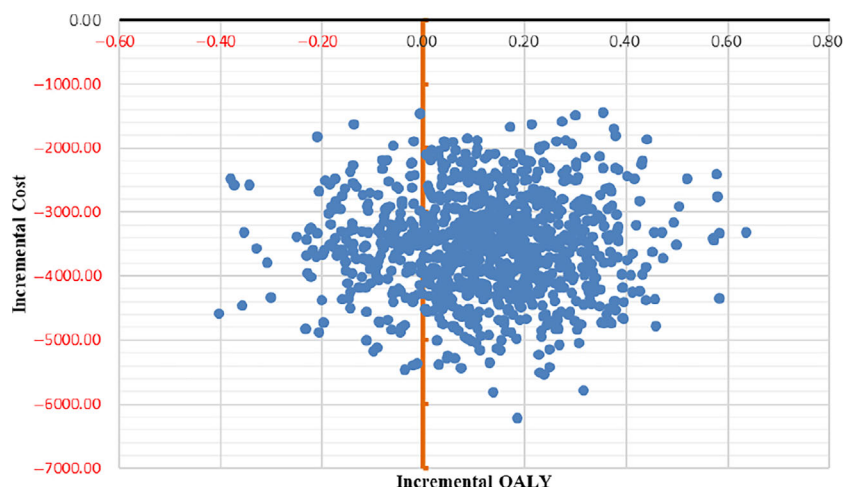


Fig. 6. Probabilistic sensitivity analysis: PhacoPPVc versus sequential procedures on 1000 iteration.

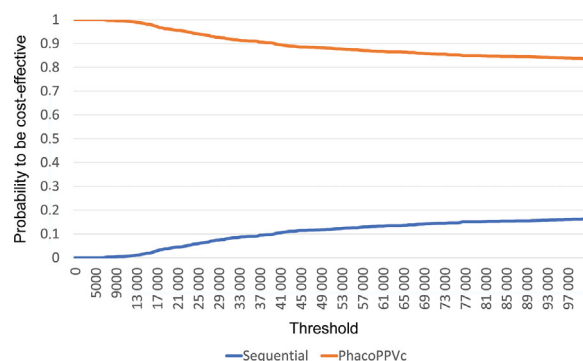


Fig. 7. Cost-effectiveness acceptability curve (CEAC) of PhacoPPVc and sequential procedures.

that policy makers should not only rely on state historic treatment rates, but also on evidence-based findings for new procedures. This would influence the provision of combining treatments by setting specific DRG weights that can facilitate effective care while containing costs. Similarly, a WHO review reported how exact requirements of the DRG system can adequately be met by adjustment of cost weight as well as the base rates from a current DRG variant (Mathauer & Wittenbecher 2012), which our present findings could also show and confirm.

Some of the major limitations with this study are that some of the costs could not be included or that outcomes were literature-based estimation, thus may have underestimated the beneficial effect of the combined surgery. However, some of these costs are considered sunk or incurred costs and would not have made a change in the decision of the intervention. In addition, the estimated cost was carefully analysed by closely recording the items and then associating to relevant national data cost estimates.

Furthermore, the QALY calculation is not based on clinical results from the patient population, but from other relevant studies. Nonetheless, the systematic validation approach utilized here provided sources that based the utility outcome on Snellen's VA scale. Similarly, most of the sources on probability and outcome measure had reported on the same scale or LogMAR but provided a converted Snellen equivalent.

The surgical cases in the study, moreover, were recorded and captured accurately followed by comprehensive search of published literature for analysis; hence, the results of this study may provide true benefit estimates of the combined surgery procedures to all the stakeholders and society at large. These parameters were further analysed for uncertainty in PSA, and same conclusion was derived from 1000 iterations.

Finally, DRG weights have a social/political effect that may have an impact to the hospital cost, but as in Norway DRGs are standardized; hence, the variation in cost may not be too far from the true cost. Nevertheless, considering that the surgical costs in other countries may differ; our study and other studies in different setting (US

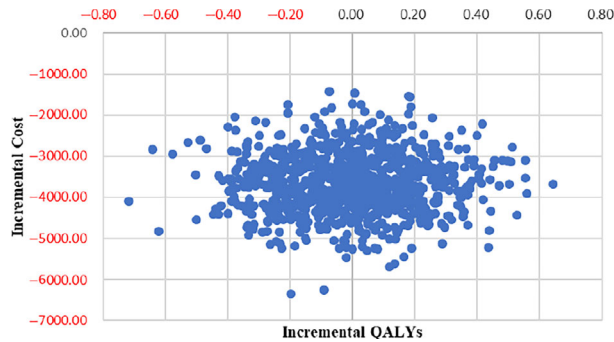


Fig. 8. Probabilistic sensitivity analysis: PhacoPPV and sequential procedures on 1000 iteration.

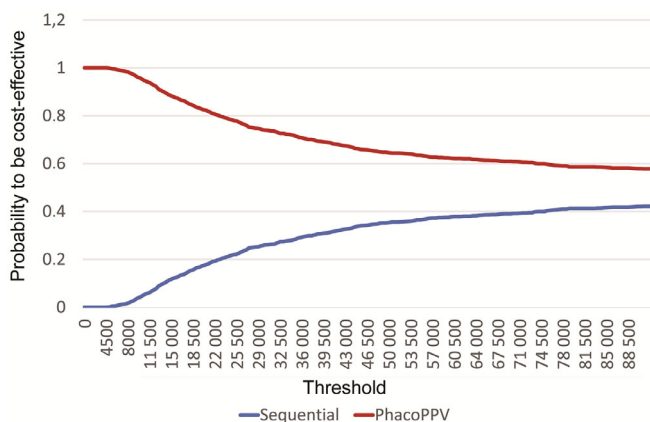


Fig. 9. Cost-effectiveness acceptability curve (CEAC) of PhacoPPV and sequential procedures.

and UK) have found similar results with combined procedures. In summary, the triple/PhacoPPVc procedure had actual benefits to the health institution, the surgeon and the patient. In the study, the mean age of the patients was  $72 \pm 9$  years; thus, this would be very beneficial for the patients in regard to saving them travel time, healing time and potentially costs. For the health institution, the double and triple procedure are cost saving, while the triple procedure provides, in addition, higher QALYs worthy of recommending new/higher DRG weights for such procedures. This will enhance best practice of using the combined procedures by more surgeons in ophthalmology and medicine in general.

#### Data Availability Statement

All data supporting the results presented in this manuscript will be made available at an institutional data storage site upon successful acceptance and publication of this work.

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## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Table S1.** Model parameters obtained from the literature.

**Table S2.** Sensitivity analysis on the discount rates.