Appendix

Formula 1-3

TM% represents the difference in knowledge between the expert and the endoscopist under training (*NOVICE*). P_{Expert} is the outcome of the procedure performed by the expert endoscopist, and P_{Novice} the predicted outcome in case the novice-trainee endoscopist completed the entire procedure. The outcome for the novice-trainee endoscopist under teleguidance P_{TM}, is in the model calculated by use of the equation as specified below.

Formula 1:

$$P_{TM} = P_{Novice} + TM\% \cdot \left(P_{Expert} - P_{Novice}\right)$$

Formula 2

The data from the dedicated literature review [8-34], were used to construct logistic regression model for the risk of post ERCP pancreatitis, bleeding, perforation, infection and death to be integrated in the health economic model. All outcomes were dependent on the four parameters; number of procedures performed by the endoscopist per year, the average age of the patients undergoing the ERCP procedures performed by the individual, % of females among those undergoing the procedures and finally the average difficulty rank of the ERCP procedures performed. For further details see Formula 2.

A four variable logistic regression models, given by Formula 2, for calculating the probability of having post ERCP complications such as pancreatitis, bleeding, perforation, infection or even a lethal outcome.

Formula 2:

$$\ln\left(\frac{P}{1-P}\right) = f\left(x_1, x_2, x_3, x_4\right) = a_0 + a_1(x_1 - \overline{x_1}) + a_2(x_2 - \overline{x_2}) + a_3(x_3 - \overline{x_3}) + a_4(x_4 - \overline{x_4})$$

$$P = \frac{\exp(f)}{1 + \exp(f)}$$

The centers correspond to the parameter values $(\overline{x_1}, \overline{x_2}, \overline{x_3}, \overline{x_4})$ from Formula 2 as detailed above. Inserting $(x_1, x_2, x_3, x_4) = (\overline{x_1}, \overline{x_2}, \overline{x_3}, \overline{x_4})$ into this equation, each outcome variable equals to the mean probabilities captured from the systematic literature review [8]. The centers $(\overline{x_1}, \overline{x_2}, \overline{x_3}, \overline{x_4})$ were calculated by numerically solving the equation $p(x_1, x_2, x_3, x_4) - p_{average} = 0$.

Formula 3

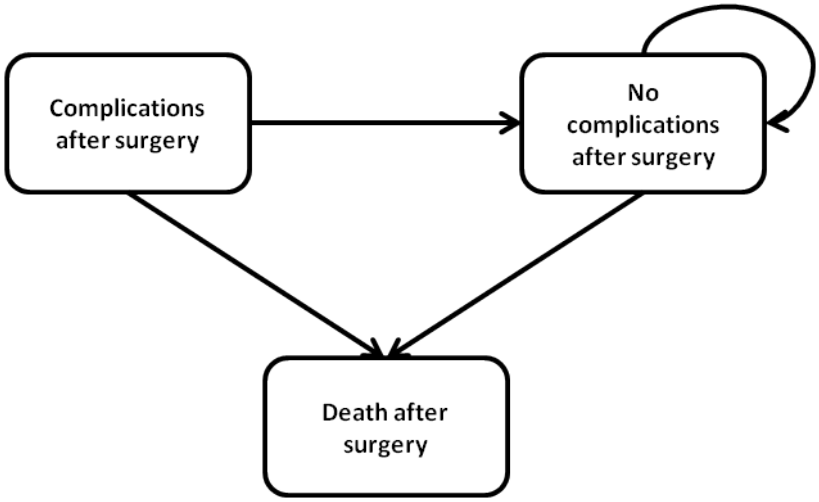
t_{TM} is the time required for a novice-trainee to reach a cannulation rate close to that of an expert, if he or she has access to teleguidance. The corresponding time to attain a cannulation rate close to that of an expert without such a training option is represented by $t_{traditional}$. t is the time the novice-trainee will use the teleguided assistance offered by the expert.

Formula 3

$$A = \begin{cases} \dfrac{t_{conventional} - t_{TM}}{2} \cdot y & if\ t \geq t_{TM} \\ \dfrac{t \cdot \sin\alpha \cdot \left(\sqrt{{t_{conventional}}^2 + y^2} + (t_{TM} - t) \cdot \dfrac{\sin\alpha + \sin\beta}{\sin\delta \cdot \sin\beta}\right)}{2 \cdot \sin\delta} & if\ t < t_{TM} \end{cases}$$

In this equation α, β and δ can be determined using algebra. When the training sessions are terminated at t before t_{TM} is reached, it was assumed that the novice-trainee will return to the traditional learning curve. This assumption will, however, most likely introduce an under-estimation of the effect. Alternatively, the cost-saving could converge into a situation between the teleguidance learning curve and the traditional learning curve and the theoretical cost savings accordingly between A($t< t_{TM}$) and A($t\geq t_{TM}$). In addition, the time span covered by the model is one year, why only A/ ($t_{traditional} \cdot ny_{novice}$) was taken into account. In the model ny_{novice} represents the number of ERCPs/year performed by the novice-trainee. Currently it was assumed that the novice-trainee will use, and has access to, the teleguidance equipment during three years. Since the depreciation time of the equipment traditionally is 3-5 years, t is set to 3 years . For the novice trainee with an initial cannulation rate of 85%, performing on an average 50 ERCP/year, t_{TM} will be 5 years, and $t_{traditional}$ 10 years.

Figure s1: Markov model defining the outcomes after hospital admission



Supplemental tables

Table s1 Probabilities, Number of professionals and length of stay.

Variable	Value	SD	Source	Distribution
Probability of pancreatitis	3.47%	0.14%	[1]	Beta
Probability of bleeding	1.34%	0.08%	[1]	Beta
Probability of perforation	0.60%	0.05%	[1]	Beta
Probability of infection	1.44%	0.09%	[1]	Beta
Probability of cardiopulmonary complications	1.33%	0.10%	[1]	Beta
Probability of ERCP death	0.33%	0.04%	[1]	Beta
Probability of PTC complications	5%	3.33%	[13]	Beta
Probability of PTC death	0.32%	0.04%	KOL	Beta
Probability of open surgery complications	10%	3%	[13]	Beta
Probability of open surgery death	0.32%	0.04%	KOL	Beta
Probability of cannulation failure ERCP (expert)	5%	0.2%	KOL	Beta
Probability of cannulation failure re-ERCP (expert)	10%	0.2%	[13]	Beta
Probability of cannulation failure ERCP (novice)	20%	0.2%	KOL	Beta
Probability of cannulation failure re-ERCP (novice)	20%	0.2%	KOL	Beta
Probability of cannulation failure PTC	3%	1.67%	[13]	Beta
Annual mortality rate in markov	f(age.gender)	-	[14]	Constant
Procedure length ERCP (hours)	0.9480	0.5173	KSdata	lognormal
Procedure length ERCP factor	1.5	-	KOL	Constant
Procedure length PTC (hours)	0.9480	0.5173	KOL	lognormal
Procedure length open surgery (hours)	2.5	1	KOL	lognormal
Number of nurses ERCP	3	-	KOL	Constant
Number of nurses PTC	3	-	KOL	Constant
Number of nurses open surgery	3	-	KOL	Constant
Number of doctors ERCP	1	-	KOL	Constant
Number of doctors PTC	1	-	KOL	Constant
Number of doctors open surgery	1	-	KOL	Constant
LOS ERCP (days)	1	0.5	[15]	Lognormal
LOS PTC (days)	2	1	KOL	Lognormal
LOS Open surgery (days)	5	2	[15]	Lognormal
Additional LOS pancreatitis (days)	4	2	[15]	Lognormal
Additional LOS bleeding (days)	4	2	[15]	Lognormal
Additional LOS perforation (days)	4	2	[15]	Lognormal
Additional LOS infection (days)	4	2	[15]	Lognormal
Additional LOS cardiopulmonary complications (days)	4	2	[15]	Lognormal
Additional LOS PTC	4	2	KOL	Lognormal

complications (days)				
Additional LOS Open surgery complications (days)	3	2	[15]	Lognormal
Additional LOS previous resurgery (days)	2	0.5	KOL	Lognormal

SD, standard deviation; ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous-transhepatic-cholangiography; LOS, length of stay

Table s2 Costs and utility estimates.

Variable	Value	SD	Source	Distribution
Expert guidance cost (SEK)	1835	-	KSdata	Constant
Additional guidance cost (SEK)	1200	-	KSdata	Constant
Cost of initial training (SEK)	300000	-	KOL	Constant
Transport to KS from center B (SEK)	34000	3400	KSdata	Lognormal
Tm equipment center B (SEK)	200000	-	KSdata	Constant
Ward/day (SEK)	6000	600	KOL	Lognormal
Hospital death (SEK)	5000	500	KOL	Lognormal
Surgery room/h (SEK)	1904	-	KSdata	Constant
Nurse salery/h (SEK)	218	21	KSdata	Lognormal
Doctor salery/h (SEK)	568	56	KSdata	Lognormal
ERCP cost (SEK)	3066	-	KSdata	Constant
ERCP supplies (SEK)	7760	776	KSdata	Lognormal
ERCP Procedure medications (SEK)	64	6	[16]	Lognormal
ERCP medications/day (SEK)	50	5	ASM	Lognormal
PTC supplies (SEK)	4438	443	[13]	Lognormal
PTC Procedure medications (SEK)	50	5	ASM	Lognormal
PTC medications/day (SEK)	50	5	ASM	Lognormal
Open surgery surgical supplies (SEK)	103084	10308	[13]	Lognormal
Open surgery Procedure medications (SEK)	50	5	ASM	Lognormal
Open surgery medications/day (SEK)	50	5	ASM	Lognormal
Treatment cost ERCP complications (SEK)	55312	5531	[13]	Lognormal
Treatment cost PTC complications (SEK)	55312	5531	[13]	Lognormal
Treatment cost Open surgery complications (SEK)	231021	23102	[13]	Lognormal
USD to SEK convertion (2016-02)	8.2388	-	[17]	Constant
EUR to SEK convertion (2016-02)	9.4114	-	[17]	Constant
Annual cost inflation	2.6%	-	KSdata	Constant
Utility of complications after ERCP	0.884	0.038	[18]	Beta
Utility of no complications after ERCP	0.9904	0.038	[18]	Beta
Age utility decrement	- 0.0003	0.0002	[19]	Normal

SD, standard deviation; ERCP, endoscopic retrograde cholangiopancreatography

Table s3 Scenario parameters – base case.

Variable	Value	SD	Source	Distribution
Cohort age	62	5	[1]	Lognormal
%females in cohort	58%	-	[1]	Constant
Number of ERCP/year expert	250	25	KOL	Lognormal
Number of ERCP/year novice	50	5	ASM	Lognormal
%expert knowledge transferred	50%	5%	ASM	Beta
Resurgery nr 1	ERCP	-	ASM	Constant
Resurgery nr 2	PTC	-	ASM	Constant
Resurgery nr 3	send to expert	-	ASM	Constant
Difficulty (1-4)	1.98	0.87	ASM	Gen. beta

SD, standard deviation; ERCP, endoscopic retrograde cholangiopancreatography

Table s4 Base case results.

	Mean	95% CI	
		Lower	Upper
Incremental costs	-369	-406	-331
Incremental QALYs	0.0005	0.00048	0.00053
INB (500k SEK per QALY)	636	595	674
Probability cost effectiveness	84.2%		
Probability cost saving	72.7%		
Probability QALY increase	91.5%		

QALY, quality-adjuste dlife year

Table s5 Key results for centers with endoscopists performing 50 ERCP per year and common resurgery strategy: ERCP-PTC-send to expert.

Expert % Difficulty	25% 2 (95% CI)	25% 3 (95% CI)	25% 4 (95% CI)	50% 2 (95% CI)	50% 3 (95% CI)	50% 4 (95% CI)	75% 2 (95% CI)	75% 3 (95% CI)	75% 4 (95% CI)
Incremental costs (SEK)	1337 (1306. 1382)	773 (738. 817)	99 (54. 151)	-359 (-395. -320)	-1542 (-1588. -1496)	-3045 (-3100. -2994)	-1777 (-1821. -1729)	-3494 (-3552. -3446)	-5726 (-5804. -5658)
Incremental QALYs	0.0003 (0.00027. 0.00033)	0.0003 (0.00027. 0.00033)	0.0004 (0.00036. 0.00045)	0.0005 (0.00048. 0.00053)	0.0007 (0.00066. 0.00073)	0.0008 (0.00076. 0.00084)	0.0008 (0.00078.0 .00083)	0.0011 (0.00106. 0.00114)	0.0013 (0.00126. 0.00134)
INB (500k SEK per QALY)	-1205 (-1252. -1252)	-608 (-654. -570)	100 45. 152)	633 (590. 672)	1894 (1842. 1945)	3456 (3398. 3518)	2183 (2133. 2230)	4028 (3974. 4088)	6381 (6310. 6463)
Probability cost effectiveness	2.0%	19.6 %	55.5 %	81.3 %	99.0 %	100%	99.4%	100%	100%
Probability cost saving	0.3%	10.5 %	45.9 %	70.7 %	98.1 %	100%	98.7%	100%	100%
Probability QALY increase	71.6 %	70.7 %	68.4 %	91.0 %	89.7 %	87.2 %	98.2%	97.1 %	97.2 %

ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous-transhepatic-cholangiography; QALY, quality-adjusted life year

Table s6 Key results for centers with endoscopists performing 100 ERCP per year and common resurgery strategy: ERCP-PTC-Open surgery.

Expert % Difficulty	**25% 2 (95% CI)**	**25% 3 (95% CI)**	**25% 4 (95% CI)**	**50% 2 (95% CI)**	**50% 3 (95% CI)**	**50% 4 (95% CI)**	**75% 2 (95% CI)**	**75% 3 (95% CI)**	**75% 4 (95% CI)**
Incremental costs (SEK)	1980 (1952. 2031)	1523 (1490. 1571)	958 (915. 1011)	496 (461. 540)	-446 (-491. -401)	-1718 (-1772. -1668)	-746 (-792. -697)	-2207 (-2261. -2150)	-4157 (-4237. -4095)
Incremental QALYs	0.0002 (0.00018. 0.00022)	0.0002 (0.00017. 0.00024	0.0003 0.00026. 0.00034)	0.0004 (0.00037. 0.00043)	0.0005 (0.00047. 0.00053)	0.0006 (-0.00056. 0.00064)	0.0006 (0.00058. 0.00063)	0.0007 (0.00067. 0.00073)	0.0009 (0.00086. 0.00088)
INB (500k SEK per QALY)	-1881 (-1934. -1849)	-1416 (-1465. -1377)	-832 (-892. -781)	-293 (-339. -253)	686 (641. 735)	2000 (1944. 2059)	1045 (995. 1093)	2575 (2516. 2627)	4622 (4555. 4706)
Probability cost effectiveness	0.0%	1.4%	16%	35.9%	81.5%	98.2 %	90.1%	99.6%	100%
Probability cost saving	0.0%	0.1%	7.7%	23.9%	71.9%	98.1 %	82.2%	99.1%	100%
Probability QALY increase	68.1%	64.6%	63.3 %	84.9%	81.8%	79.5 %	93.8%	92.0%	91.6%

ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous-transhepatic-cholangiography; QALY, quality-adjusted life year

Table s7 Key results for centers with endoscopists performing 50 ERCP per year and common resurgery strategy: PTC-send to expert.

Expert % Difficulty	25% 2 (95% CI)	25% 3 (95% CI)	25% 4 (95% CI)	50% 2 (95% CI)	50% 3 (95% CI)	50% 4 (95% CI)	75% 2 (95% CI)	75% 3 (95% CI)	75% 4 (95% CI)
Incremental costs (SEK)	1395 (1358. 1454)	1054 (1030. 1108)	677 (626. 742)	-110 (-164. -47)	-779 (-844. -717)	-1597 (-1677. -1522)	-1393 (-1468. -1321)	-2565 (-2659. -2485)	-3843 (-3966. -3743)
Incremental QALYs	0.0002 (0.00018. 0.00022)	0.0003 (0.00027. 0.00033)	0.0002 (0.00017. 0.00024)	0.0005 (0.00048. 0.00053)	0.0005 (0.00047. 0.00053)	0.0005 (0.00047. 0.00054)	0.0008 (0.00078. 0.00083)	0.0008 (0.00077. 0.00083)	0.0008 (0.00077. 0.00084)
INB (500k SEK per QALY)	-1281 (-1338. -1240)	-925 (-980. -879)	-568 (-636. -513)	351 (288. 408)	1042 (975. 1111)	1842 (1765. 1922)	1774 (1699. 1853)	2972 (2892. 3068)	4255 (4152. 4378)
Probability cost effectiveness	2.8%	11.0 %	28.7 %	66.8 %	85.8 %	93.4 %	93.9 %	98.6 %	99.7 %
Probability cost saving	1.3%	7.1%	21.1 %	57.5 %	78.5 %	91.4 %	90.1 %	97.5 %	99.3 %
Probability QALY increase	72.9 %	68.8 %	61.8 %	90.0 %	84.1 %	79.5 %	98.4 %	96.9 %	92.1 %

ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous-transhepatic-cholangiography; QALY, quality-adjusted life year

Table s8 Key results for centers with endoscopists performing 100 ERCP per year and common resurgery strategy: PTC-send to expert.

Expert % Difficulty	25% 2 (95% CI)	25% 3 (95% CI)	25% 4 (95% CI)	50% 2 (95% CI)	50% 3 (95% CI)	50% 4 (95% CI)	75% 2 (95% CI)	75% 3 (95% CI)	75% 4 (95% CI)
Incremental costs (SEK)	2034 (1997. 2094)	1697 (1653. 1756)	1458 (1408 . 1517)	734 (676. 795)	136 (71. 204)	-526 (-610. -449)	-419 (-494. -340)	-1415 (- 1505. - 1326)	-2530 (- 2651. - 2432)
Incremental QALYs	0.000 2 (0.000 18. 0.000 22)	0.000 2 (0.000 17. 0.000 22)	0.000 1 (- 0.000 07. 0.000 14)	0.000 4 (0.000 38. 0.000 42)	0.000 4 (0.000 37. 0.000 43)	0.000 3 (0.000 27. 0.000 34)	0.000 5 (0.000 48. 0.000 53)	0.000 6 (0.000 57. 0.000 63)	0.000 5 (0.000 47. 0.000 54)
INB (500k SEK per QALY)	-1953 (- 2016. - 1912)	-1602 (- 1660. - 1557)	-1383 (- 1447. - 1328)	-557 (-622. -501)	46 (-22. 113)	683 (601. 771)	688 (607. 763)	1716 (1622. 1811)	2788 (2689. 2914)
Probability cost effectiveness	0.1%	1.1%	5.1%	27.7%	52.5%	71.2%	73.8%	88.9%	95.3%
Probability cost saving	0.0%	0.7%	3.1%	20.9%	45.8%	66.2%	65.9%	85.6%	94.0%
Probability QALY increase	65.9%	66.7%	58.8 %	85.3%	80.0%	68.6%	94.3%	91.2%	82.3%

ERCP, endoscopic retrograde cholangiopancreatography; PTC, percutaneous-transhepatic-cholangiography; QALY, quality-adjusted life year

Table s9 Key results for centers with endoscopists performing 50 ERCP per year and common resurgery strategy: send to expert.

Expert %: Difficulty:	**25% 2 (95% CI)**	**25% 3 (95% CI)**	**25% 4 (95% CI)**	**50% 2 (95% CI)**	**50% 3 (95% CI)**	**50% 4 (95% CI)**	**75% 2 (95% CI)**	**75% 3 (95% CI)**	**75% 4 (95% CI)**
Incremental costs (SEK)	227 (190 277)	-678 (-721. -625)	-1813 (-1867. -1756)	-2423 (-2470. -2639)	-4146 (-4206. -4091)	-6453 (-6535. -6384)	-4837 (-4906. -4768)	-7433 (-7514. -7361)	-10961 (-11073. -10866)
Incremental QALYs	0.0003 (0.00027. 0.00033)	0.0004 (0.00037. 0.00044	0.0005 (0.00046. 0.00055)	0.0006 (0.00057. 0.00063)	0.0007 (0.00067. 0.00074)	0.0010 (0.00096. 0.00105)	0.0008 (0.00077. 0.00083)	0.0011 (0.00107. 0.00114)	0.0015 (0.00146. 0.00155)
INB (500k SEK per QALY)	-85 (-136. -44)	861 (807. 907)	2070 (2008. 2132)	2699 (2646. 2748)	4514 (4454. 4575)	6963 (6890. 7050)	5248 (5177. 5316)	7996 (7920. 8080)	11721 (11620. 11831)
Probability cost effectiveness	49.3 %	84.7 %	97.8 %	99.7 %	100%	100%	100%	100%	100%
Probability cost saving	42.9 %	81.7 %	97.5 %	99.4 %	100%	100%	100%	100%	100%
Probability QALY increase	72.8 %	72.0 %	74.3 %	91.3 %	89.6 %	91.1 %	97.4 %	98.4 %	97.8 %

ERCP, endoscopic retrograde cholangiopancreatography; QALY, quality-adjusted life year

Table s10 Key results for centers with endoscopists performing 100 ERCP per year and common resurgery strategy: send to expert.

Expert %: Difficulty:	**25% 2 (95% CI)**	**25% 3 (95% CI)**	**25% 4 (95% CI)**	**50% 2 (95% CI)**	**50% 3 (95% CI)**	**50% 4 (95% CI)**	**75% 2 (95% CI)**	**75% 3 (95% CI)**	**75% 4 (95% CI)**
Incremental costs (SEK)	896 (859.948)	134 (90.186)	-929 (-980.-874)	-1480 (-1532.-1428)	-3080 (-3136.-3023)	-5206 (-5286.-5139)	-3751 (-3818.-3694)	-6145 (-6228.-6074)	-9297 (-9413.-9201)
Incremental QALYs	0.0002 (0.00018.0.00023)	0.0003 (0.00027.0.00033)	0.0003 (0.00026.0.00035)	0.0004 (0.00038.0.00043)	0.0005 (0.00047.0.00054)	0.0007 (0.00066.0.00075)	0.0006 (0.00058.0.00063)	0.0008 (0.00077.0.00083)	0.0011 (0.00106.0.00115)
INB (500k SEK per QALY)	-803 (-861.-762)	-2 (-58.45)	1101 (1040.1154)	1678 (1627.1730)	3352 (3291.3605)	5570 (5497.5656)	4045 (3986.4111)	6558 (6486.6641)	9848 (9749.9962)
Probability cost effectiveness	14.5%	52.4%	88.7%	98.0%	99.8%	100%	99.9%	100%	100%
Probability cost saving	9.7%	46.0%	87.5%	96.5%	99.7%	100%	99.9%	100%	100%
Probability QALY increase	66.0%	67.4%	65.3%	83.2%	83.1%	84.2%	93.9%	94.4%	94.2%

ERCP, endoscopic retrograde cholangiopancreatography; QALY, quality-adjusted life year

Table s11 Estimated cost saving for one endoscopist as a function of the learning effect introduced by TM. The maximal cost saving is determined using the area in between curves (**Fig. 2a** shows the case when the cannulation rate for the novice is 85%) and the cost saving when the tm equipment is used 3 years is calculated using (**Fig. 2b**) and equation (3) (with t=3). Because the model carries the time horizon of 1 year only, one-tenth of the cost saving divided by the Number of ERCP/y is implemented in the model as a cost decrement.

Cannulation rate novice %	**Maximal cost saving with TM (50 ERCP/y) (SEK)**	**Cost saving with TM used 3 years (50 ERCP/y) (SEK)**	**Maximal cost saving with TM (100 ERCP/y) (SEK)**	**Cost saving with TM used 3 years (100 ERCP/y) (SEK)**
85	929049	780401	1858098	1560802
86	855686	731585	1711372	1463170
87	779078	678921	1558155	1357843
88	706516	628533	1413031	1257067
89	632214	575125	1264428	1150251
90	553007	515260	1106013	1030520
91	479199	457846	958397	915693
92	403283	394924	806565	789847
93	327201	326441	654403	652883
94	250208	250208	500416	500416
95	171220	171220	342440	342440
96	88656	88656	177313	177313
97	1818	1818	3636	3636

TM, teleguidance-assisted procedure; ERCP, endoscopic retrograde cholangiopancreatography