

# Cost-Utility Analysis of Add-on Stiripentol vs Cannabidiol and Fenfluramine in Dravet Syndrome in the USA

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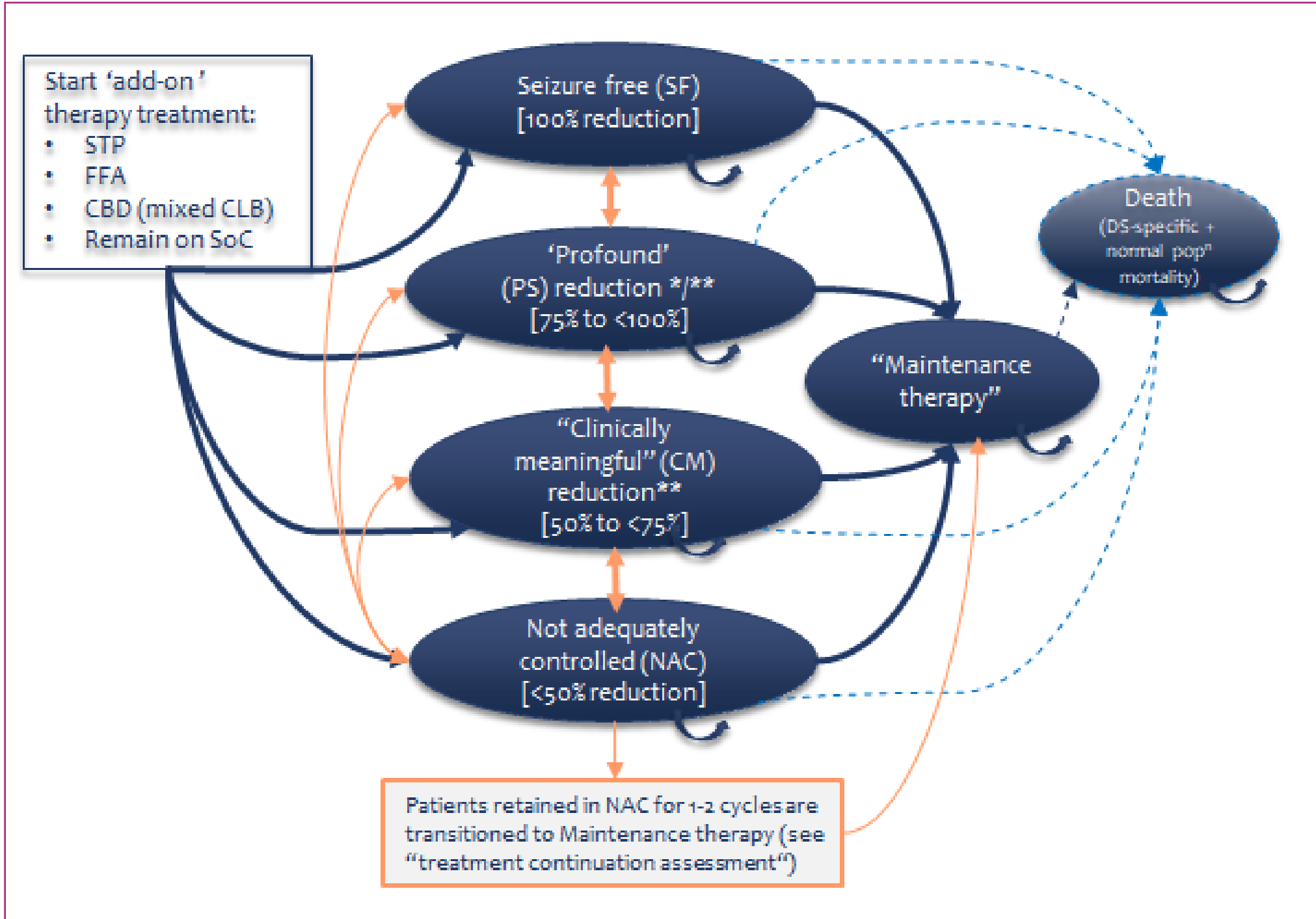
## INTRODUCTION

- Dravet syndrome (DS) is a rare epileptic encephalopathy characterised by frequent (often daily) convulsive seizures, 'comorbidities' and premature mortality <sup>1,2</sup>.
- Arising in the first years of life, the severe treatment-resistant seizures are associated with a progressive decline in behavioral, motor and cognitive function ('comorbidities') <sup>1,3</sup>.
- An estimated 15-20% of children with DS die from status epilepticus (SE), sudden unexpected death in epilepsy (SUDEP), and accidents before reaching adulthood <sup>2</sup>.
- The daily burden of DS significantly impacts the quality of life (QoL) of patients, as well as their carers and the broader family members <sup>3</sup>.
- Reducing convulsive seizure frequency is a key goal of treatment to decrease the risks of morbidity and mortality, improve QoL, and lower healthcare system expenditure <sup>1,3,7</sup>.
- Despite the use of combination standard of care (SoC) anti-seizure medications (ASMs), seizures are often intractable and sustained periods of seizure freedom [SF] is rarely possible.
- 'Add-on' therapies to background SoC ASMs are therefore often required to improve seizure control. Stiripentol (STP, DIACOMIT®) <sup>4</sup>, pharmaceutical grade cannabidiol (CBD, EPIDIOLEX®) <sup>5</sup>, and fenfluramine (FFA, FINTEPLA®) <sup>6</sup> are specifically licensed for DS in the USA, for use from ages 6 months (≥7kg body weight), 1-year, and 2-years, respectively.
- A recent US-led international consensus-based DS treatment algorithm positions STP and FFA ahead of CBD in the treatment pathway <sup>7</sup>. Several network meta-analyses (NMA) of RCT data support this positioning on a clinical basis <sup>8-9</sup>. However, no published economic analyses have evaluated the comparative cost-effectiveness of all three licensed add-on therapies.
- This study assessed the cost-effectiveness (utility) of initiating STP versus CBD, or FFA, or continued background ASM therapy in DS patients, from a US healthcare payer perspective.

## METHODS

- Informed by a systematic literature review identifying economic evaluations of STP (n=5), CBD (n=3), and FFA (n=3), a Markov model was developed in Microsoft Excel®
- The model simulated a cohort of DS patients requiring a first-line add-on therapy to their existing background ASMs (comprising valproate [VPA] and clobazam [CLB]).
- In base case analyses, patients aged 2 years old (the earliest common age patients could receive all three add-on therapies <sup>4-6</sup>) entered the model and were assigned to either continue receiving their background ASMs, or receive add-on STP, CBD, or FFA.
- Patients were initially distributed across health states based on risk differences versus STP in the proportion of patients achieving each respective level of seizure reduction as derived from a published NMA <sup>9</sup> (Table 1).
- In subsequent 3-monthly cycles, patients could then transition between the 6 health states defined by: a percentage reduction from baseline in monthly convulsive seizures (MCSF); receiving Maintenance Therapy (add on therapy removed; background ASMs only), or death (see Figure 1).
- Probabilities for the subsequent transitions between health states, discontinuation of add-on therapies for adverse events, and SoC ASMs usage and doses during 'Maintenance therapy', were derived from patient-level analyses of the DIAVEY<sup>10</sup> real-world observational study of STP and applied equally to all model arms (Table 1).
- Patients failing to achieve a ≥50% reduction in MCSF within 3 months (1 cycle) of starting treatment were assumed to discontinue add-on therapy and transition to the 'Maintenance therapy' health state. Similarly, patients residing in the 'Not adequately controlled' [NAC] health state for 6 months (2 cycles) also transitioned to 'Maintenance therapy' (Figure 1).

Figure 1: Cost utility analysis Markov model structure



CBD, Cannabidiol; CM, clinically meaningful seizure reduction state; DS, Dravet syndrome; FFA, fenfluramine; NAC, not adequately controlled; PS, profound seizure reduction state; SF, seizure free state; SoC, background ASMs; STP, stiripentol.

Health states:

- Seizure Free (SF) = 100% reduction from baseline in monthly convulsive seizure frequency (MCSF);
- 'Profound Seizure' (PS) reduction = 75% to <100% in MCSF;
- 'Clinically Meaningful' (CM) reduction = 50% to <75% in MCSF;
- 'Not Adequately Controlled' (NAC) = <50% reduction in MCSF;
- 'Maintenance Therapy' (add-on therapy removed; background ASMs only)
- 'Death' (absorbing health state).

At each cycle (3 months), patients transition freely between SF, PS, CM and NAC health states. Arrows represent possible movements between health states.

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- Seizure events are associated with an increased risk of premature mortality <sup>1,2</sup>, as RCTs cannot feasibly be powered to provide mortality data in DS, no treatment-related differences in mortality were modelled. A DS-specific mortality rate <sup>2</sup> was applied to US general population life tables <sup>12</sup> and equally applied to all modelled arms (Table 1).
- DS-specific utility values and resource use were obtained from 3 studies <sup>11</sup> identified in a SLR (Table 1). Average utility values from the 3 studies were mapped to the 'Maintenance therapy' health state, and proportionally adjusted for 'seizure free' [SF], 'profound seizure' [PS] reduction, 'clinically meaningful' [CM] seizure reduction, and NAC health states based on the relative % reduction in MCSF.
- Drug costs were calculated on an average cost per mg basis using commercially available bottle/pack sizes and formulations; and January 2024 wholesale acquisition costs (WACs) <sup>13</sup>. In the base case analyses, real-world add-on drug doses <sup>16, 17</sup> were used (Table 1). Dispensing fees, co-payments, co-insurance and rebates for all drugs were pragmatically assumed to be zero.
- Other direct costs and medical resource use associated with seizure events and no seizure events were derived from a published database analysis of 989 Medicaid and commercially insured DS patients in the US between 2010 and 2015 and inflated to 2023 values <sup>14</sup> (Table 1). The costs of periodic echocardiogram monitoring for FFA, per license requirements <sup>6</sup>, were also included.
- Accident, SE and adverse events were implicitly assumed to be captured in seizure-event resource use, costs, and utility values within health states; alongside routine treatment appointments.
- Base case analyses adopted a 15-year time horizon and a US commercial insurer (payer) perspective in 2024. Costs and QALYs were discounted at 3% per year and varied (0-6%) in sensitivity analyses <sup>15</sup>.
- Results were presented as ICERs (incremental costs per quality-adjusted life year [QALY] gained) and NMBs (incremental net monetary benefits) at the Institute for Clinical and Economic Review organization (ICERO) willingness-to-pay (WTP) threshold of \$200,000/QALY <sup>15</sup> (Table 2). A positive NMB indicates a cost-effective therapy option at a given WTP threshold. **The add-on therapy with the highest NMB is considered the most cost-effective (economically preferred) therapy.**
- Base case parameter values subject to uncertainty were varied within their 95% confidence range (or else +/-20%) in one-way sensitivity analyses (OWSA). Combined uncertainty was assessed using probabilistic sensitivity analyses (PSA: 1,000 Monte Carlo simulations).

Table 1. Cost utility analysis model parameters

Parameter	Base case value					Source
Patient age; weight	2 years; 12.34kg					Centers for Disease Control & Prevention [12]
Efficacy - First cycle health state probabilities						
	SF	PS	CM	NAC	Maint.	Guerrini et al 2024 [9]
STP	36.36%	18.18%	15.15%	30.30%	0.00%	
SoC ASMs	0.00%	3.23%	3.23%	93.55%	0.00%	
FFA	10.36%	38.18%	20.15%	31.30%	0.00%	
CBD*	3.36%	10.64%	12.12%	73.88%	0.00%	
Efficacy - Subsequent cycle transition probabilities (from row to column health states)						
	SF	PS	CM	NAC	Maint.	DIAVEY study [10]
SF	92.05%	1.01%	0.94%	5.04%	0.96%	
PS	1.35%	92.27%	3.36%	2.07%	0.96%	
CM	0.97%	3.40%	88.36%	6.30%	0.96%	
NAC	0.66%	1.02%	2.04%	95.32%	0.96%	
Maint.	0.00%	0.00%	0.00%	0.00%	100.00%	
Mortality						
DS Mortality, probability/year	1.45%					Cooper et al 2016 [2]
Drug therapy dosing and costs						
Add-on therapy dosing	Age <16 years	Age 16 to <18 years		Age 18+ years		
STP (mg/kg/day)	50	34		25		Balestrini et al 2022; Chiron et al 2018 [16]
CBD (mg/kg/day)	15	15		15		Scheffer et al 2021 [17]; D'Onofrio et al 2020 [17]
FFA (mg/kg/day)	0.44	0.44		0.44		Sullivan et al 2020 [17]
Add-on therapy WAC, costs per mg (US\$/mg)						
STP	\$0.1251					Analysource® [13]
CBD	\$0.1625					Micromedex® Red Book [13]
FFA	\$24.3960					
SoC ASM dosing & WAC	Dosing (mg/kg/day)		Costs per mg (US\$/mg)**			
VPA	25.2		\$0.0038			STICLO trials [16]; Red Book [13]
CLB	0.5		\$0.9093			
Maintenance therapy dosing and WAC	Dosing (mg/kg/day)		Costs per mg (US\$/mg)**		Proportion of patients on treatment	
VPA	42.50		\$0.0038		70.97%	DIAVEY study [10]; Red Book [13]
CLB	1.25		\$0.9093		35.48%	
TOP	10.00		\$0.0875		38.71%	
LEV	70.00		\$0.0078		9.68%	
CLON	0.20		\$2.9698		19.35%	
ETHO	30.00		\$0.0036		12.90%	
ZON	7.00		\$0.1237		12.90%	
Health state utility values						
SF	0.760					Average of Lo et al 2021; Auvin et al 2021; Radu et al 2019 [11]
PS	0.567					
CM	0.350					
NAC	0.341					
Maint.	0.341					
Death	0.000					Assumption
Direct resource use and costs						
Units of resource use by health state per year	SF	PS	CM	NAC	Maint.	
Inpatient admissions	0.2	0.5	0.5	0.8	0.8	Reaven et al 2019 [14]
ED visit	0.2	1.0	1.0	1.8	1.8	
Hospital OP visit	6.1	7.0	7.0	8.0	8.0	
Physician visit	9.2	10.7	10.7	12.4	12.4	
Other OP visit	7.3	9.1	9.1	11.1	11.1	
Home health	5.6	5.7	5.7	5.7	5.7	
Equipment/ supply	1.1	1.0	1.0	0.8	0.8	
Rescue drugs	0.5	1.0	1.0	1.5	1.5	
Other drugs	14.8	15.0	15.0	15.1	15.1	
Costs per unit of resource use by health state (2023 US\$)	SF	PS	CM	NAC	Maint.	
Inpatient admissions	\$15,031	\$24,844	\$24,844	\$28,451	\$28,451	Reaven et al 2019, inflated to 2023 prices [14]
ED visit	\$1,701	\$2,074	\$2,074	\$2,210	\$2,210	
Hospital OP visit	\$876	\$944	\$944	\$999	\$999	
Physician visit	\$213	\$231	\$231	\$244	\$244	
Other OP visit	\$202	\$229	\$229	\$247	\$247	
Home health	\$417	\$309	\$309	\$199	\$199	
Equipment/ supply	\$592	\$502	\$502	\$421	\$421	
Rescue drugs	\$465	\$591	\$591	\$657	\$657	
Other drugs	\$185	\$184	\$184	\$184	\$184	
Other features						
Time horizon	15 years					Assumption
Discount rate	3% costs and outcomes					ICRO [15]
Initial treatment continuation assessment	6 months					Per previous NICE HTAs of CBD and FFA [18]
ASMs: antiseizure medications; CBD, cannabidiol; CLB, clobazam; CLON, clobazepam; CM, clinically meaningful seizure reduction state; ED, emergency department; ETHO, ethosuximide; FFA, fenfluramine; HTAS, health technology assessments; LEV, levetiracetam; Maint., maintenance therapy state; NAC, not adequately controlled state; OP, outpatient; PS, profound seizure reduction state; SF, seizure free state; SoC, standard of care; STP, stiripentol; TOP, topiramate; US, United States; VPA, valproate; WAC, wholesale acquisition costs; ZON, zonisamide						
* For CBD 15mg/kg/day used in the base case model, a mean average of the matrices for the CBD 10mg/kg/day and 20mg/kg/day is used. For the scenario analysis using maximum doses, only the CBD 20mg/kg/day matrix is used (data not shown).						
** Costs per mg rounded to 4 decimal places in this table (with exception of VPA). Unrounded figures used in model.						

## RESULTS

- In base case analyses, vs continued background SoC ASMs, STP generated the greatest QALY gains (+0.66), followed by FFA (+0.53) and CBD (+0.15) (Table 2, Figure 2).

Figure 2. Cumulative QALYs gained over time (30 year time horizon) for a) background ASMs, b) STP, c) CBD and d) FFA

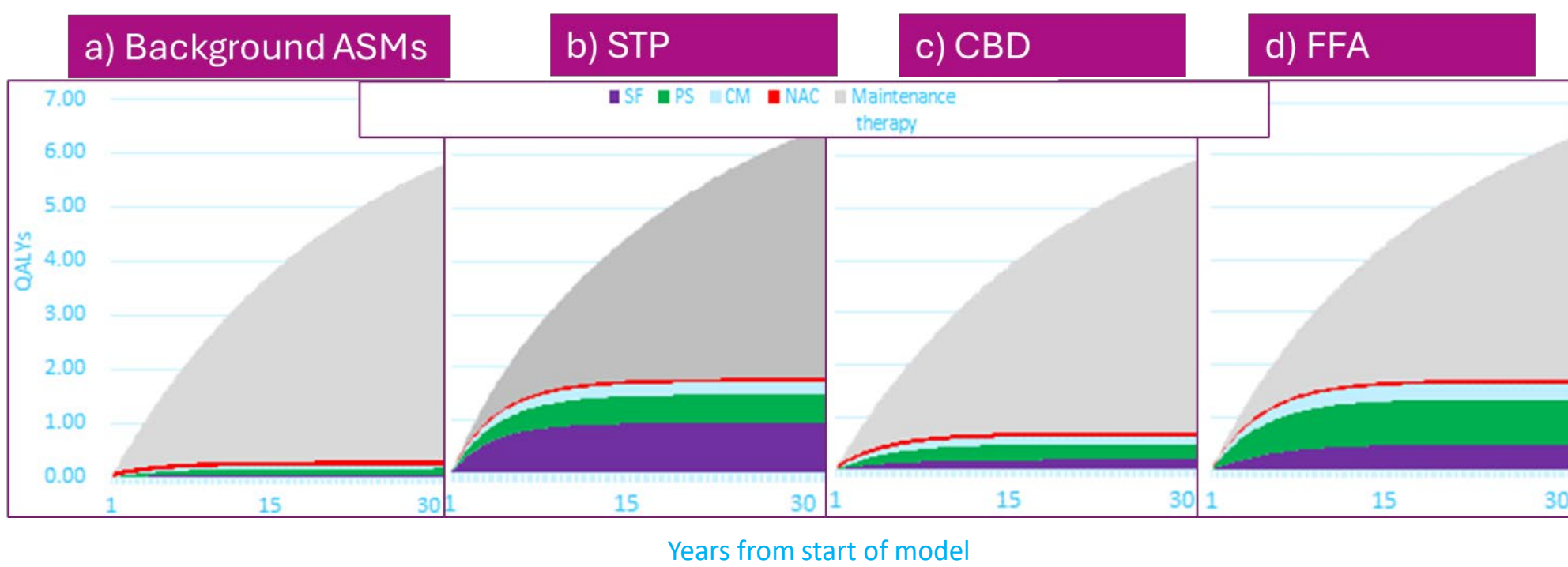
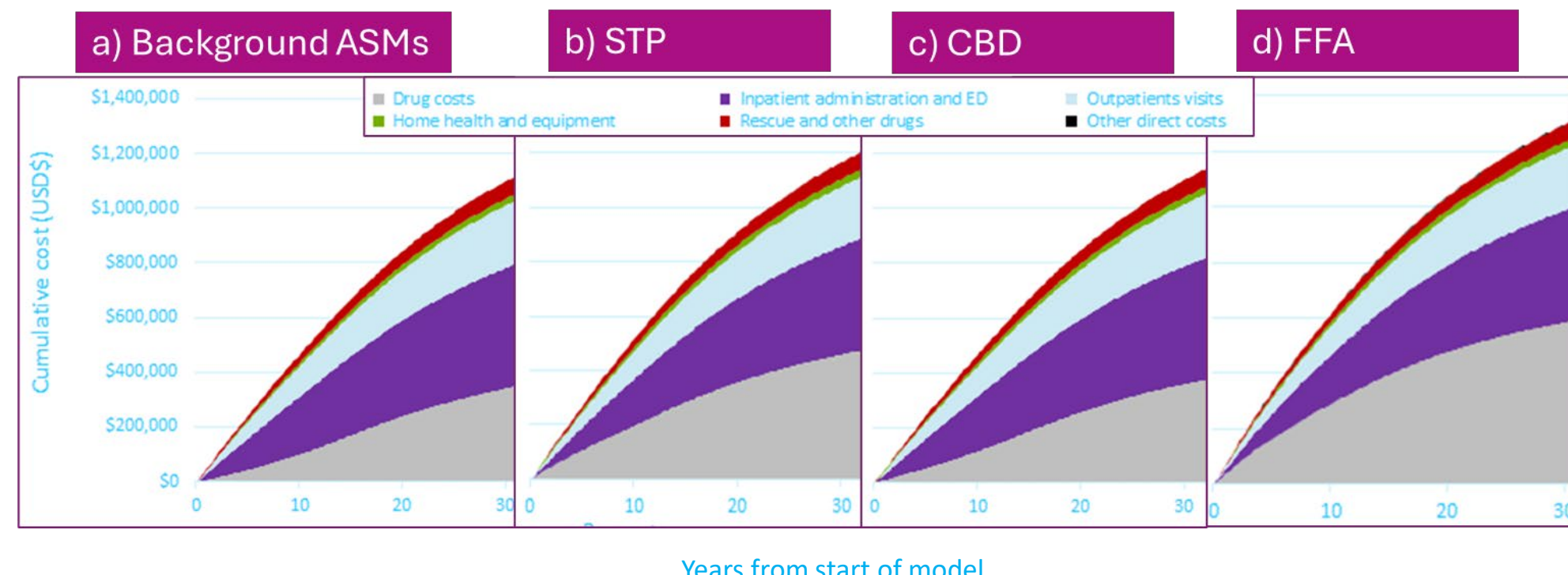


Figure 3. Cumulative costs (\$USD) over time (30 year time horizon) for a) background ASMs, b) STP, c) CBD and d) FFA



- NMBs were greatest with STP (\$67,511), followed by CBD (\$24,825), and then FFA (-\$76,830) (Table 2). STP economically dominated FFA, generating more QALYs (+0.13) and costing (-\$118,676) less (Table 2). STP was cost effective versus CBD, with an ICER of \$116,448/QALY.
- In OWSA, the most influential parameters on the base case ICER results were the patient weight, and direct healthcare resource use costs in 'Maintenance therapy'. For all parameters explored, ICERs for STP and CBD versus continued background SoC ASMs, remained below the WTP threshold. All ICERs for FFA exceeded the threshold.

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**Disclosures:** The WAC prices (2023) for medicines included in the analyses of the accepted abstract were accurate at the time of submission. This poster presents analyses incorporating updated WAC prices (2024) for medicines. This study was funded by Biocodex, the manufacturer of DIACOMIT® (stiripentol). CM, MF, BS, and CS are employees of Biocodex, the manufacturer of stiripentol. YY and DA are employees of Adelphi Values (PROVE), paid consultants to Biocodex. All authors abided by their ongoing confidentiality and contractual obligations.

Table 2. Base case cost utility analysis results

Ranked treatments by QALYs (best to worst)	vs background ASM					vs next non-dominated best therapy*
	Cost, \$US	QALY	Incr. Cost (\$)	Incr. QALY	ICER (\$/QALY)	NMB (\$) at \$200k/QALY WTP
<b>STP+ VPA+CLB</b>	\$729,107	4.47	\$63,986	0.66	\$97,319/ QALY	\$67,511
<b>FFA+ VPA+CLB</b>	\$847,783	4.34	\$182,661	0.53	\$345,195/ QALY	-\$76,830
<b>CBD+ VPA+CLB</b>	\$669,565	3.96	\$4,443	0.15	\$30,363/ QALY	\$24,825
<b>VPA+CLB (background ASM)</b>	\$665,122	3.81	-	-	-	-

ASM, antiseizure medication; CBD, cannabidiol; CLB, clobazam; FFA, fenfluramine; Incr., incremental; ICER, incremental cost effectiveness ratio (i.e., incremental cost per QALY gained); NMB, incremental net monetary benefits; QALY, quality-adjusted life year; STP, stiripentol; VPA, valproate sodium; WTP, willingness to pay

\* STP dominates FFA as is both more effective and less costly than FFA. In rank order of QALYs gained, the fully incremental analyses therefore compares: background ASMs (VPA+CLB) vs CBD+VPA+CLB and then the 'next non-dominated best therapy' CBD+VPA+CLB vs STP+VPA+CLB.

Note: This table presents rounded figure. Calculations to derive the reported NMBs and ICERs use unrounded figures.

- In PSA, probabilistic mean ICERs versus background SoC ASMs were similar to the deterministic base case ICERs. The probability that STP and CBD had ICERs <\$200,000/QALY exceeded 95%, whereas FFA had a probability <5%. The probabilities that STP was cost effective versus CBD and FFA were 97% and 100%, respectively.
- In scenario analyses, including: initiation at age 6 months or in adults; longer or shorter time horizons; use of maximum licensed dosing; and adoption of a societal perspective, STP was economically preferred. STP was the only add-on therapy with a positive NMB when initiated in adults. STP retained the highest NMB at a WTP threshold of \$150,000/QALY used by ICERO<sup>15</sup> to benchmark value-based prices (Table 3).

Table 3. Cost-utility analysis scenario analyses – Net monetary benefit (NMB)

Scenario	Base case	Scenario	NMB* (\$) vs background ASMs		
<b>A positive NMB indicates a cost-effective therapy option at a given WTP threshold</b>			STP	FFA	CBD
<b>Base case</b>			<b>\$67,511</b>	<b>-\$76,830</b>	<b>\$24,825</b>
Patient age at add-on initiation [4-6]	2 years	STP=6mths; CBD=12mths†; FFA=24mths†	<b>\$95,159</b>	-\$60,363	-\$29,038
Time horizon [15]	15 years	5 years	<b>\$1,127</b>	-\$538,831	-\$25,009
Payer type [14]	Commercial	Medicaid	<b>\$66,726</b>	-\$80,710	\$24,836
Dosing approach [4,16, 17]	RW doses for all add-on therapies	Alternative STP RW doses (US) : - Pediatric: 27.58 mg/kg/day - Age16-<18ys: 23.80 mg/kg/day - Adult: 15.20 mg/kg/day [23] - Lowest RW doses for all add-on therapies: - STP: as above (US) [23] - CBD: 10 mg/kg/day [25] - FFA: 0.39 mg/kg/day [29] Maximum licensed doses for all add-on therapies: - STP: 50 mg/kg/day - CBD: 20 mg/kg/day - FFA: 0.7 mg/kg/day	<b>\$126,831</b>	-\$76,830	\$24,825
			<b>\$126,831</b>	-\$48,912	\$32,917
Treatment continuation assessment [18]	3 mths	6 months	<b>\$54,449</b>	-\$96,351	\$18,779
Perspective [14]	Healthcare payer	Societal	<b>\$139,611</b>	-\$21,060	\$41,656
WTP threshold [15]	\$200,000/QALY	\$150,000/QALY	<b>\$34,637</b>	-\$103,289	\$17,508
		\$50,000/QALY	<b>\$1,763</b>	-\$129,746	<b>\$10,191</b>
			-\$31,111	-\$156,204	<b>\$2,874</b>