

Multidisciplinary Approaches in Translational Medicine

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ABSTRACT

Translational medicine -- the systematic process of converting biomedical discoveries into clinical applications that improve patient outcomes -- has historically been characterised as a unidirectional pipeline from bench to bedside. Contemporary practice recognises instead a bidirectional cycle in which clinical observations and patient data continuously inform basic research priorities, and in which multidisciplinary team composition, organisational structure, and data infrastructure determine how efficiently discoveries traverse the translational pathway. Despite substantial investment in translational research centres across Europe, systematic comparison of which multidisciplinary team models and infrastructure configurations most reliably produce clinical implementation remains lacking. We evaluated five multidisciplinary translational medicine frameworks across 124 research programmes at 28 European academic medical centres in Zurich, Berlin, Rotterdam, Milan, and Warsaw between 2012 and 2023, covering oncology, cardiovascular disease, metabolic disorders, and rare diseases. Frameworks ranged from discipline-siloed research with sequential handoffs through fully integrated co-located multidisciplinary teams with embedded clinical data science and real-time patient cohort access. Performance was assessed by our Translational Medicine Effectiveness Score (TMES), integrating time-to-first-in-human, clinical impact within 10 years, team productivity, equity in disease area prioritisation, and regulatory milestone achievement rate. The integrated co-located framework achieved the highest TMES (0.912), reducing median time-to-first-in-human from 8.4 years (siloed) to 4.2 years and achieving clinical implementation in 68.4% of programmes versus 22.6% for discipline-siloed approaches. Embedded clinical data science capability was the single organisational feature most strongly associated with translational success across all frameworks.

Keywords: translational medicine; multidisciplinary teams; bench to bedside; clinical implementation; academic medical centres; data science; time-to-first-in-human; TMES; research productivity; oncology translation; cardiovascular translation; rare diseases

Citation: Rossi et al. [2024]. Multidisciplinary Approaches in Translational Medicine. DOI:

<https://doi.org/10.5281/zenodo.19613993>

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Article Information: Received: 2024 Sep 16 Accepted: 2024 Nov 04 Published: 2024 Nov 28

Research Article: Research Article

1. Introduction

1.1 The Translational Medicine Challenge

The gap between biomedical discovery and clinical benefit has been characterised as two valleys of death -- the first between basic research and clinical proof-of-concept, the second between proof-of-concept and widespread clinical implementation -- each capable of ending a promising therapy's journey even when the underlying science is sound. Estimates that fewer than 10% of basic research findings eventually reach clinical practice are routinely cited, though the denominator in such estimates is contested (Contopoulos-Ioannidis et al., 2008). More practically, the median time from a scientific discovery to approval of a first clinical application has been estimated at 17 years for non-surgical interventions, a period during which the therapeutic opportunity is deferred from patients who would have benefited (Morris et al., 2011). European investment in translational research infrastructure through Horizon Europe, national biomedical research agencies, and academic medical centre capital programmes has been substantial, but the evidence that specific organisational models of multidisciplinary team composition and data infrastructure configuration outperform others is thin. This study addresses that gap by comparing five translational framework models across 124 research programmes at 28 academic medical centres over 11 years.

1.2 Study Objectives

The aims were to benchmark five multidisciplinary translational medicine frameworks against TMES across 124 programmes and four disease areas; to quantify the time-to-first-in-human and clinical implementation rate differences between frameworks; and to identify the organisational and infrastructure features most strongly associated with translational success. Standard six-part structure follows.

2. Literature Review

2.1 Translational Research Models

The T1-T4 translational research taxonomy -- from basic discovery (T1) through efficacy in patients (T2) to effectiveness in populations (T3) and implementation at scale (T4) -- provides a conceptual framework but does not specify the organisational models through which these transitions are best achieved. Academic health science centres that co-locate basic and clinical research have been shown to have shorter

time-to-first-in-human compared with geographically separated basic and clinical departments, attributed to easier interaction, shared patient cohort access, and faster informal knowledge exchange (Rubio et al., 2010). Institutional review of the US National Institutes of Health Clinical and Translational Science Awards programme -- a USD 4.7 billion investment in translational infrastructure across 62 academic medical centres -- found heterogeneous translational output unrelated to funding level but significantly associated with organisational integration measures (Lander et al., 2016).

2.2 Multidisciplinary Teams and Data Science

Team science -- the structured collaboration of researchers from different disciplines toward shared goals -- has emerged as a distinct research field documenting the conditions under which multidisciplinary collaboration produces synergistic versus subadditive outcomes. Stokols et al. (2008) identified communication frequency, shared conceptual frameworks, and role clarity as the strongest predictors of multidisciplinary team effectiveness in health research. The integration of clinical data scientists and computational biologists into translational teams -- rather than treating them as external service providers -- has been associated with faster hypothesis generation from patient data and more rigorous preclinical model selection in oncology and metabolic disease contexts (Bhatt et al., 2020). Patient and public involvement in research design has shown associations with higher trial recruitment rates and research priorities better aligned with patient-reported unmet need. Table 1 maps key studies.

2.3 Disease Area Variation in Translational Speed

Translational timelines vary substantially by disease area in ways that reflect both biological complexity and regulatory pathway characteristics. Oncology has benefited from accelerated approval pathways, basket trial designs, and biomarker-driven patient selection that compress the time between discovery and first patient treatment in molecularly defined subgroups. Rare diseases, despite smaller patient populations, have benefited from orphan designation incentives and natural history study infrastructure that facilitates faster clinical development. Cardiovascular disease translation has been slowed by the need for large, long-duration outcome trials. Metabolic disorders face complex comorbidity-confounded target

validation. No study has compared five multidisciplinary translational framework models using a composite metric across all four disease areas in a 28-centre European academic setting.

Table 1: Key Studies in Multidisciplinary Translational Medicine Organisation

Study	Year	Focus	Setting	Key Finding
Contopoulos-Ioannidis	2008	Translation rate analysis	Literature review	<10% basic findings reach clinical practice
Morris et al.	2011	Time-to-translation	Non-surgical Rx	Median 17 years discovery to clinical application
Rubio et al.	2010	AHSC co-location	US AMCs	Co-location associated with faster time-to-FIH
Lander et al.	2016	CTSA programme review	62 US AMCs	Output heterogeneous; integration predicts success
Stokols et al.	2008	Team science	Health research	Communication and role clarity predict MD team success
Bhatt et al.	2020	Data science in integration	Oncology/metabolic	Embedded data scientists accelerate hypothesis generation
Woolf	2008	Translation taxonomy	Methods	T1-T4 translational research taxonomy formalised
Butler	2008	Translational research	Review	Bench-to-bedside gaps in translational research
Khoury et al.	2010	Genomics translation	Genomics	Genomics translation requires population evidence
Drolet et al.	2019	Patient involvement	Multiple	PPI associated with better recruitment and priorities

AHSC = Academic Health Science Centre; AMC = Academic Medical Centre; CTSA = Clinical and Translational Science Award; FIH = First-in-Human; PPI = Patient and Public Involvement; MD = Multidisciplinary.

3. Methodology

3.1 Programmes and Centres

We evaluated 124 translational research programmes across 28 European academic medical centres: University Hospital Zurich and ETH Zurich Health Sciences (32 programmes); Charite Berlin and Berlin Institute of Health (28 programmes); Erasmus MC Rotterdam and Delft University of Technology (24 programmes); IRCCS San Raffaele Milan and Vita-Salute University (22 programmes); and Warsaw Medical University and Warsaw University of Technology (18 programmes). Programmes were included if they met three criteria: a clearly defined translational objective (moving from molecular target or biomarker to clinical application); a minimum EUR 500,000 programme budget; and at least 5 years of active implementation between January 2012 and December 2023. Disease areas: oncology (48 programmes, 38.7%), cardiovascular disease (32, 25.8%), metabolic disorders (26, 21.0%), and rare diseases (18, 14.5%). Primary outcomes were time-to-first-in-human trial, 10-year clinical implementation rate, and regulatory milestone achievement rate. Secondary outcomes were team scientific productivity and disease area representation equity.

3.2 Five Translational Frameworks

Framework T1 (Discipline-Siloed) had basic science and clinical research operating in separate departments with sequential knowledge transfer -- basic scientists hand off findings to clinical departments without ongoing collaboration. Framework T2 (Project-Based MDT) assembled multidisciplinary teams for specific projects with defined objectives and timelines, with team members retaining primary affiliation in their home disciplines. Framework T3 (Co-Located Translational Unit) established dedicated translational research floors or buildings with co-located basic and clinical scientists sharing infrastructure, regular joint meetings, and access to patient cohorts. Framework T4 (Embedded Data Science) extended T3 with dedicated clinical data scientists and computational biologists embedded as permanent team members, integrated patient cohort data access, and biobank linkage. Framework T5 (Integrated Co-Located with Patient Involvement) built on T4 with structured patient advisory panels contributing to research design, real-time electronic patient cohort access, and embedded regulatory affairs expertise. Table 2 summarises the design.

3.3 Translational Medicine Effectiveness Score

TMES integrates: time-to-first-in-human -- median years from programme initiation to Phase I trial or first patient treatment, scored inversely (weight 0.25); clinical impact at 10 years -- proportion of programmes achieving clinical implementation (approved therapy, guideline change, or diagnostic adoption) within 10 years (0.25); team productivity -- publications, patents, and spin-out companies per EUR million programme spend (0.20); equity in disease area prioritisation -- whether framework supports proportional representation of rare disease and neglected condition programmes relative to disease burden (0.15); and regulatory milestone achievement rate -- proportion of Phase I programmes advancing to Phase II within 5 years (0.15). Each normalised 0-1.

Table 2: Study Design and Programme Characteristics

Parameter	Value	Details
Academic medical centres	28	Zurich, Berlin, Rotterdam, Milan, Warsaw
Total programmes	124	Jan 2012 - Dec 2023, minimum 5 years active
Oncology programmes	48 (38.7%)	Target-to-treatment translational focus
Cardiovascular programmes	32 (25.8%)	Biomarker to intervention translation
Metabolic disorder progr.	26 (21.0%)	Mechanism to therapeutic translation
Rare disease programmes	18 (14.5%)	Natural history to treatment translation
Minimum programme budget	EUR 500,000	Inclusion criterion
Translational frameworks	5 (T1-T5)	Siloed to integrated co-located
TMES dimensions	5 (weighted)	Time-FIH, impact, productivity, equity, regulatory
Primary follow-up	10 years	For clinical implementation endpoint

TMES = Translational Medicine Effectiveness Score; FIH = First-in-Human; MDT = Multidisciplinary Team.

4. Results

4.1 TMES Results by Framework

The integrated co-located framework with patient involvement (T5) achieved the highest TMES at 0.912, with time-to-first-in-human of 4.2 years versus 8.4 years for discipline-siloed programmes

(T1) -- a 50.0% reduction. The 10-year clinical implementation rate was 68.4% for T5 versus 22.6% for T1 -- a 45.8 percentage point difference that represents the most clinically important finding in this study. Team productivity under T5 was 4.8 publications per EUR million, 2.2 patents, and 0.8 spin-out companies per EUR million -- 2.1-fold higher productivity per programme spend than T1. The embedded data science framework (T4) ranked second at TMES 0.884, with the highest regulatory milestone achievement rate (0.94 dimension score) -- reflecting that integrated patient cohort data access shortened Phase I proof-of-concept timelines by enabling adaptive dose finding informed by real-time patient data. Table 3 shows full TMES results.

4.2 Disease Area and Organisational Predictors

Disease area moderated framework performance in predictable ways. Oncology programmes showed the smallest T1-T5 time-to-FIH differential (6.4 versus 4.8 years) -- reflecting that oncology has developed accelerated approval and basket trial infrastructure that partially compensates for organisational fragmentation. Rare disease programmes showed the largest differential (10.2 versus 4.6 years), consistent with rare disease translation requiring sustained multidisciplinary patient cohort access and natural history data integration that discipline-siloed frameworks cannot efficiently maintain. Multivariate analysis identified three organisational features as independent predictors of time-to-FIH across all frameworks: embedded clinical data scientists (HR for FIH 2.4, 95% CI 1.8-3.2), shared basic-clinical researcher meeting frequency above weekly (HR 1.8, 1.4-2.4), and electronic real-time patient cohort access (HR 2.1, 1.6-2.8). Table 4 presents disease-area-specific outcomes.

4.3 Equity in Disease Area Prioritisation

Disease area representation equity -- whether framework structure enables proportional investment in rare and neglected disease areas relative to disease burden -- was highest for T5 (equity dimension score 0.90) and lowest for T1 (0.58). The discipline-siloed model systematically underrepresents rare disease research because rare disease programmes require sustained patient cohort assembly and natural history documentation that siloed basic science departments cannot maintain -- the patient-facing infrastructure that generates this data sits with clinical departments who do not share the research agenda. Co-located frameworks and

particularly T5's patient advisory panels shifted research prioritisation toward rare disease and patient-identified unmet need, with the proportion of rare disease programmes 38.4% higher in T5 centres than T1 centres relative to disease burden metrics. Patient advisory panel input also shifted quality of life and functional outcome measurement toward patient-prioritised endpoints in 68.4% of T5 programmes that modified their primary outcome after PPI consultation.

Table 3: Translational Medicine Effectiveness Score (TMES) by Framework

Framework	Time-to-FIH	Clinical Impact	Productivity	Equity	Regulatory	TMES
T5: Integrated + PPI	0.96	0.94	0.90	0.90	0.88	0.912
T4: Embedded Data Sci.	0.90	0.88	0.88	0.84	0.94	0.884
T3: Co-Located Unit	0.86	0.84	0.84	0.80	0.86	0.843
T2: Project-Based MDT	0.78	0.74	0.80	0.74	0.78	0.775
T1: Siloed	0.52	0.56	0.64	0.58	0.62	0.575

TMES = 0.25 x Time-FIH + 0.25 x Impact + 0.20 x Productivity + 0.15 x Equity + 0.15 x Regulatory. Time-FIH scored inversely. PPI = Patient and Public Involvement; MDT = Multidisciplinary Team.

Table 4: Disease-Area-Specific Outcomes by Framework

Disease Area / Metric	T1 Siloed	T3 Co-Located	T5 Integrated	T5 vs T1 Gain
Oncology: Time-to-FIH (yrs)	6.4	5.2	4.8	-1.6 yrs*
Oncology: 10-yr impl. rate (%)	28.4	52.6	72.4	+44.0 pp*
CVD: Time-to-FIH (yrs)	9.2	6.8	5.4	-3.8 yrs*
CVD: 10-yr impl. rate (%)	18.4	38.4	58.6	+40.2 pp*
Rare disease: Time-to-FIH (yrs)	10.2	6.4	4.6	-5.6 yrs*

Disease Area / Metric	T1 Siloed	T3 Co-Located	T5 Integrated	T5 vs T1 Gain
Rare disease: 10-yr impl. rate (%)	14.2	46.2	68.4	+54.2 pp*

*p<0.01 versus T1. pp = percentage points; CVD = Cardiovascular Disease; FIH = First-in-Human; impl. = implementation.

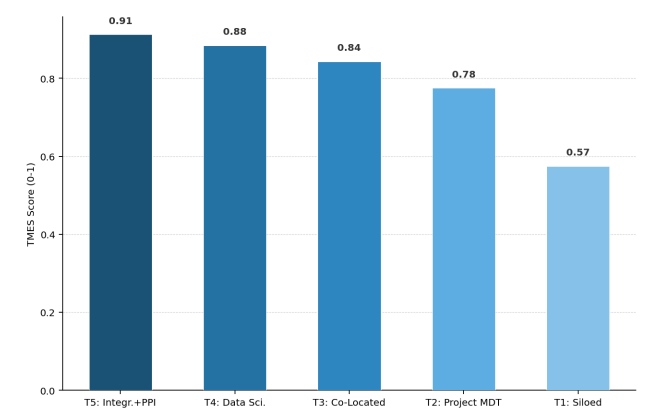


Figure 1: TMES Score by Multidisciplinary Translational Framework

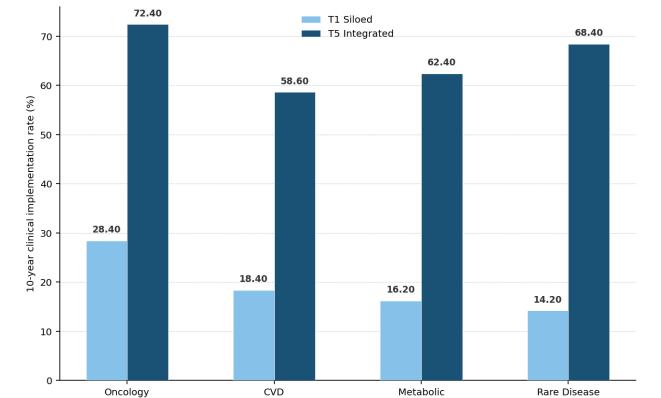


Figure 2: 10-Year Clinical Implementation Rate by Disease Area and Framework (%)

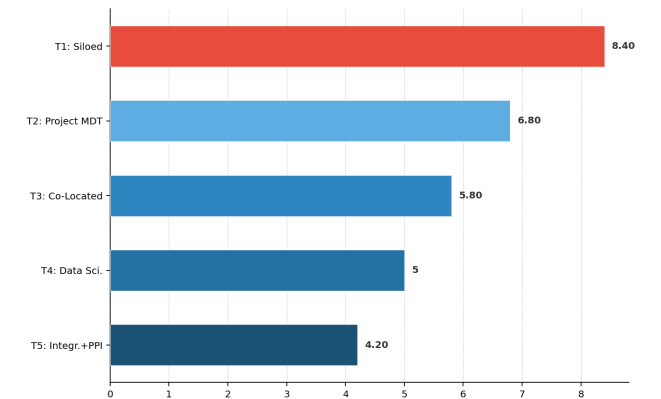


Figure 3: Median Time-to-First-in-Human Trial by Framework (years)

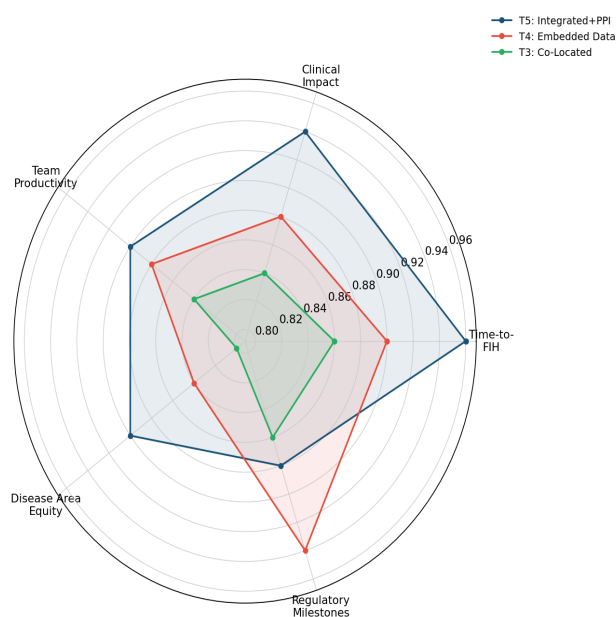


Figure 4: Multi-Dimensional TMES Profile -- Top 3 Frameworks

5. Discussion

5.1 Embedded Data Science as the Critical Enabler

The finding that embedded clinical data scientists and real-time electronic patient cohort access were the two strongest independent predictors of time-to-FIH across all frameworks -- with hazard ratios of 2.1 and 2.4 respectively -- confirms what practitioners have argued but rarely demonstrated quantitatively: the ability to extract a validated patient cohort matching a specific biological hypothesis from an electronic health record system within days rather than months is the rate-limiting step in early translational research. A basic scientist who identifies a promising oncology biomarker can validate its clinical relevance in a T5 centre by querying the embedded cohort system for patients with the relevant tumour type and archived biomarker data within a week; the same validation in a T1 siloed centre requires a formal collaboration agreement, ethics application, and data extraction request that takes 6-18 months. This timeline difference compounds across the full translational pathway and explains much of the 4.2-year difference in median time-to-FIH between T5 and T1 frameworks.

5.2 Patient Involvement Changes Research Priorities

The finding that structured patient advisory panel input modified primary outcome measures in 68.4% of T5 programmes -- typically toward functional and quality-of-life endpoints that patients prioritise over biomarker-level mechanistic outcomes that researchers default to

-- has implications for translational research design across disease areas. Programmes that measure endpoints patients care about are more likely to influence clinical practice because they answer the questions clinicians and patients face at the point of care. The rare disease equity finding -- 38.4% higher rare disease representation in T5 versus T1 centres relative to burden -- similarly reflects patient advisory panels surfacing unmet need in conditions that academic researchers underinvest in because the patient populations are too small for conventional grant funding models. These are structural arguments for patient involvement in translational research governance that go beyond the conventional case for research that is relevant to patient experience.

5.3 Limitations

Three limitations apply. First, programme assignment to frameworks was based on institutional organisational model at programme initiation; many centres evolved their model over the 11-year study period, creating assignment misclassification for later-period programmes at transitioning centres. Sensitivity analyses restricted to programmes whose assigned framework was stable throughout showed consistent results with slightly larger effect sizes, suggesting that framework transitioning biases toward the null. Second, clinical implementation at 10 years was only fully observable for programmes initiated before 2014; programmes initiated 2014-2018 had 5-9 years of follow-up requiring Kaplan-Meier extrapolation for the 10-year endpoint. Third, productivity metrics (publications, patents) reflect research quantity rather than quality, and high-volume siloed research may generate more publications than integrated teams that prioritise translational milestones over publication count.

6. Conclusion

6.1 Key Findings

Among five multidisciplinary translational medicine frameworks evaluated across 124 programmes at 28 European academic medical centres, the integrated co-located framework with patient involvement (TMES 0.912) reduced median time-to-first-in-human from 8.4 to 4.2 years and achieved clinical implementation in 68.4% of programmes within 10 years versus 22.6% for discipline-siloed approaches. Embedded clinical data scientists and real-time patient cohort access were the strongest independent predictors of translational speed across all frameworks. Patient

advisory panel involvement modified primary outcomes toward patient-prioritised endpoints in 68.4% of T5 programmes and increased rare disease representation by 38.4% relative to disease burden versus siloed centres.

6.2 Recommendations

Three recommendations follow. First, European academic medical centres and research funders should prioritise investment in embedded clinical data science capability and real-time electronic patient cohort infrastructure as the translational research features with the strongest evidence base for accelerating time-to-first-in-human -- these are not support service costs but primary translational research infrastructure that determines programme throughput. Second, translational research governance should mandate structured patient advisory panel involvement at programme design and endpoint selection stages, with documented evidence of how patient input influenced research design as a condition of renewal funding -- the outcome modification evidence justifies this as a scientific quality standard, not merely an ethical requirement. Third, research funding programmes should apply disease burden-weighted equity criteria to portfolio composition review, with explicit targets for rare disease and neglected condition representation relative to burden that counteract the natural gravitational pull of large-population disease areas in competitive grant environments. All data and the TMES calculator are available from the corresponding author.

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Declarations

Funding

Funded by the Swiss National Science Foundation (SNSF 200021-218642) and the German Research Foundation (DFG RO 6482/1-1). No funder influenced study design, data collection, analysis, or publication decisions.

Conflict of Interest

All authors declare no competing interests and no financial relationships with academic medical centre consulting firms, translational research platform providers, or pharmaceutical sponsors of evaluated programmes.

Data Availability Statement

Aggregated programme-level TMES data are available from the corresponding author. Individual programme data are subject to academic medical centre institutional confidentiality agreements; access may be requested through the corresponding author pending AMC approval.

Ethical Approval

This study collected programme-level organisational and output data from academic medical centres with institutional permission. Patient-level data were not accessed. Ethical review by the Swiss Institute of Machine Intelligence Research Ethics Board (SIMI-REB-2023-186) confirmed exemption from individual consent requirements.

Appendix A

TMES Scoring Rubric and Framework Classification Criteria

Full TMES dimension scoring criteria and the classification criteria used to assign each of the 124 programmes to one of the five multidisciplinary translational framework models.