

Leveraging natural language processing and machine learning methods for adverse drug event detection in electronic health/medical records: A scoping review.

Drug Safety (DRSA)

*Su Golder PhD¹, DongFang Xu PhD², Karen O'Connor MSc³, Yunwen Wang PhD², Mahak Batra MSc¹, Professor Graciela Gonzalez Hernandez²

¹Department of Health Sciences, University of York, York, United Kingdom

²Department of Biostatistics, Epidemiology and Informatics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA

³Department of Computational Biomedicine, Cedars-Sinai Medical Center, West Hollywood, CA, USA

*Corresponding Author:

Su Golder BSc (hons), MSc, FRSA, PhD

Associate Professor

Department of Health Sciences

University of York

York, YO10 5DD

Tel: 01904 321904

Email: su.golder@york.ac.uk

Twitter: [@SuGolder](https://twitter.com/SuGolder)

Supplementary Material

Search Strategies

1. Ovid MEDLINE(R) ALL <1990 to July 13, 2023>

Query results from 18 Jul 2023

Click to run:

<https://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=c4s1RHRnnTZWJxM7j8Ms5zVblyBA8hXGtyHJFEskLEmPhsOtLFH7mCDMRE3wvJYM>

1	exp Artificial Intelligence/	175,391
2	natural language processing.ti,ab,ot,kw,kf.	7,824
3	text mining.ti,ab,ot,kw,kf.	4,105
4	information extraction.ti,ab,ot,kw,kf.	1,900
5	clinical language processing.ti,ab,ot,kw,kf.	8
6	artificial intelligence.ti,ab,ot,kw,kf.	36,643
7	machine learning.ti,ab,ot,kw,kf.	90,717
8	deep learning.ti,ab,ot,kw,kf.	49,379
9	predictive modeling.ti,ab,ot,kw,kf.	3,361
10	data mining.ti,ab,ot,kw,kf.	13,893
11	supervised learning.ti,ab,ot,kw,kf.	5,424
12	unsupervised learning.ti,ab,ot,kw,kf.	2,601
13	(automated adj5 (detection or extraction or identification)).ti,ab,ot,kw,kf.	12,600
14	or/1-13	286,399

15	(adverse adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	586,567
16	side effect\$.ti,ot,ab,kw,kf.	304,754
17	(unintended adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	2,246
18	(unintentional adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	333
19	(unwanted adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	7,927
20	(unexpected adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	8,325
21	(undesirable adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	10,286
22	(serious adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	54,361
23	(toxic adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	67,369
24	{adrs or ades}.ti,ot,ab,kw,kf.	7,169
25	drug safety.ti,ot,ab,kw,kf.	6,836
26	(drug surveillance or ((postmarketing or post marketing) adj2 surveillance)).ti,ot,ab,kw,kf.	4,011
27	product surveillance.ti,ot,ab,kw,kf.	148
28	drug monitoring.ti,ot,ab,kw,kf.	14,056
29	tolerability.ti,ot,ab,kw,kf.	59,218
30	treatment emergent.ti,ot,ab,kw,kf.	7,361
31	toxicity.ti,ot,ab,kw,kf.	473,223
32	pharmacovigilance.ti,ot,ab,kw,kf.	7,631
33	drug withdrawal*.ti,ot,ab,kw,kf.	4,421
34	ae.fs.	1,993,295
35	to.fs.	480,819
36	Product Surveillance, Postmarketing/	7,628
37	Adverse Drug Reaction Reporting Systems/	8,826
38	pharmacovigilance/	3,306
39	Drug Monitoring/	23,555
40	exp Drug Hypersensitivity/	49,666
41	exp "Drug-Related Side Effects and Adverse Reactions"/	132,167
42	Abnormalities, Drug-Induced/	14,739
43	Safety-Based Drug Withdrawals/	416
44	Drug Recalls/	157
45	safety signal*.ti,ot,ab,kw,kf.	3,206
46	or/15-45	3,355,112
47	14 and 46	12,820
48	medical records systems, computerized/ or electronic health records/	45,813
49	Electronic Health Record*.ti,ot,ab,kw,kf.	29,247
50	(EHR or EHRs).ti,ab,ot,kw,kf.	12,957
51	electronic medical record*.ti,ot,ab,kw,kf.	26,272
52	digital health record*.ti,ot,ab,kw,kf.	52
53	digital medical record*.ti,ab,ot,kw,kf.	90
54	(emr or emrs).ti,ot,ab,kw,kf.	9,808
55	computeri?ed medical record*.ti,ot,ab,kw,kf.	931
56	computeri?ed health record*.ti,ot,ab,kw,kf.	34
57	Automated Medical Record*.ti,ot,ab,kw,kf.	97
58	Automated health Record*.ti,ot,ab,kw,kf.	4
59	or/48-58	86,682
60	47 and 59	755

61	Unstructured.ti,ot,ab,kw,kf.	12,701
62	(note or notes).ti,ot,ab,kw,kf.	147,027
63	narrative*.ti,ot,ab,kw,kf.	76,445
64	free text.ti,ot,ab,kw,kf.	6,622
65	nonstructured.ti,ot,ab,kw,kf.	261
66	descript* text.ti,ot,ab,kw,kf.	114
67	open text.ti,ot,ab,kw,kf.	373
68	electronic text.ti,ot,ab,kw,kf.	36
69	text box.ti,ot,ab,kw,kf.	58
70	text field*.ti,ot,ab,kw,kf.	293
71	or/61-70	240,510
72	60 and 71	204

2. Embase Search Strategy

Click to run:

<https://ovidsp.ovid.com/ovidweb.cgi?T=JS&NEWS=N&PAGE=main&SHAREDSEARCHID=6drXR6932gbdfcgPhY3BBnC2pCQ6lBdb0NhKBbe5vEMG9bi263KSSH20EJM9sCBCs>

Embase <1990 to 2023 Week 27>

#	Query	Results from 14 Jul 2023
1	natural language processing/	10,274
2	exp Artificial Intelligence/	82,270
3	natural language processing.ti,ab,ot,kw,kf.	9,163
4	text mining.ti,ab,ot,kw,kf.	4,354
5	information extraction.ti,ab,ot,kw,kf.	1,944
6	clinical language processing.ti,ab,ot,kw,kf.	5
7	artificial intelligence.ti,ab,ot,kw,kf.	43,753
8	machine learning.ti,ab,ot,kw,kf.	107,499
9	deep learning.ti,ab,ot,kw,kf.	57,161
10	predictive modeling.ti,ab,ot,kw,kf.	4,147
11	data mining.ti,ab,ot,kw,kf.	18,176
12	supervised learning.ti,ab,ot,kw,kf.	6,264
13	unsupervised learning.ti,ab,ot,kw,kf.	2,937
14	(automated adj5 (detection or extraction or identification)).ti,ab,ot,kw,kf.	16,303
15	or/1-14	264,210
16	(adverse adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	895,580
17	side effect\$.ti,ot,ab,kw,kf.	383,433
18	(unintended adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	2,692
19	(unintentional adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	420
20	(unwanted adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	9,292
21	(unexpected adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	10,568
22	(undesirable adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	11,714
23	(serious adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	83,840

24	(toxic adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).ti,ot,ab,kw,kf.	67,622
25	(adrs or ades).ti,ot,ab,kw,kf.	13,395
26	drug safety.ti,ot,ab,kw,kf.	11,277
27	(drug surveillance or ((postmarketing or post marketing) adj2 surveillance)).ti,ot,ab,kw,kf.	5,623
28	product surveillance.ti,ot,ab,kw,kf.	339
29	drug monitoring.ti,ot,ab,kw,kf.	21,217
30	tolerability.ti,ot,ab,kw,kf.	107,155
31	treatment emergent.ti,ot,ab,kw,kf.	18,763
32	toxicity.ti,ot,ab,kw,kf.	582,245
33	pharmacovigilance.ti,ot,ab,kw,kf.	15,457
34	drug withdrawal*.ti,ot,ab,kw,kf.	5,593
35	ae.fs.	1,108,959
36	to.fs.	465,969
37	exp adverse drug reaction/	491,646
38	exp postmarketing surveillance/	38,121
39	exp adverse effect/	820,559
40	exp drug safety/	547,182
41	exp drug monitoring/	44,087
42	exp Drug Hypersensitivity/	63,675
43	exp side effect/	648,817
44	exp product recall/	1,717
45	safety signal*.ti,ot,ab,kw,kf.	8,837
46	or/16-45	3,399,206
47	15 and 46	12,779
48	electronic medical record system/ or electronic medical record/	81,997
49	Electronic Health Record*.ti,ot,ab,kw,kf.	44,245
50	(EHR or EHRs).ti,ab,ot,kw,kf.	20,470
51	electronic medical record*.ti,ot,ab,kw,kf.	56,697
52	digital health record*.ti,ot,ab,kw,kf.	87
53	digital medical record*.ti,ab,ot,kw,kf.	240
54	(emr or emrs).ti,ot,ab,kw,kf.	23,717
55	computeri?ed medical record*.ti,ot,ab,kw,kf.	1,215
56	computeri?ed health record*.ti,ot,ab,kw,kf.	39
57	Automated Medical Record*.ti,ot,ab,kw,kf.	61
58	Automated health Record*.ti,ot,ab,kw,kf.	4
59	or/48-58	146,095
60	47 and 59	1,055
61	Unstructured.ti,ot,ab,kw,kf.	14,500
62	(note or notes).ti,ot,ab,kw,kf.	174,135
63	narrative*.ti,ot,ab,kw,kf.	85,369
64	free text.ti,ot,ab,kw,kf.	10,718
65	nonstructured.ti,ot,ab,kw,kf.	249
66	descript* text.ti,ot,ab,kw,kf.	135
67	open text.ti,ot,ab,kw,kf.	535
68	electronic text.ti,ot,ab,kw,kf.	59
69	text box.ti,ot,ab,kw,kf.	197

70	text field*.ti,ot,ab,kw,kf.	477
71	or/61-70	281,632
72	60 and 71	287

3. PsycInfo Search Strategy

APA PsycInfo <1987 to August Week 4 2023>

1	exp Artificial Intelligence/	30630
2	data collection/ or data mining/ or data processing/	12000
3	natural language processing.mp.	2170
4	text mining.mp.	989
5	information extraction.mp.	378
6	clinical language processing.mp.	1
7	artificial intelligence.mp.	14501
8	machine learning.mp.	17121
9	deep learning.mp.	3575
10	predictive modeling.mp.	580
11	data mining.mp.	4613
12	supervised learning.mp.	1193
13	unsupervised learning.mp.	713
14	(automated adj5 (detection or extraction or identification)).mp.	682
15	or/1-13	52232
16	(adverse adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	48894
17	side effect\$.mp.	53664
18	(unintended adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	1025
19	(unintentional adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	109
20	(unwanted adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	1001
21	(unexpected adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	2296
22	(undesirable adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	1447
23	(serious adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	4181
24	(toxic adj2 (interaction\$ or response\$ or effect\$ or event\$ or reaction\$ or outcome\$)).mp.	1782
25	(adrs or ades).mp.	512
26	drug safety.mp.	1415
27	(drug surveillance or ((postmarketing or post marketing) adj2 surveillance)).mp.	476
28	product surveillance.mp.	257
29	drug monitoring.mp.	1825
30	tolerability.mp.	8220
31	treatment emergent.mp.	1710
32	toxicity.mp.	10386
33	Drug Effects.mp.	3584
34	pharmacovigilance.mp.	391
35	drug withdrawal*.mp.	5607
36	"side effects (drug)"/ or "side effects (treatment)"/ or drug allergies/ or drug interactions/	32996
37	exp safety/ or exp patient safety/	35135
38	vigilance/ or monitoring/	11693

39	safety signal*.mp.	412
40	or/16-39	165083
41	medical records systems, computerized/ or electronic health records/	1308
42	exp Medical Records/ or exp Electronic Health Records/	4854
43	Electronic Health Record*.mp.	3901
44	(EHR or EHRs).mp.	1244
45	electronic medical record*.mp.	2519
46	digital health record*.mp.	9
47	digital medical record*.mp.	8
48	(emr or emrs).mp.	784
49	computeri?ed medical record*.mp.	77
50	computeri?ed health record*.mp.	4
51	Automated Medical Record*.mp.	12
52	Automated health Record*.mp.	2
53	Unstructured.mp.	5278
54	(note or notes).mp.	68789
55	narrative*.mp.	85840
56	free text.mp.	1003
57	nonstructured.mp.	105
58	descript* text.mp.	69
59	open text.mp.	112
60	electronic text.mp.	85
61	text box.mp.	42
62	text field*.mp.	42
63	exp Health Information Technology/	6151
64	or/41-63	167581
65	15 and 40 and 64	114

4. IEEE Xplore Search Strategy

((adverse effect* OR adverse event* OR adverse reaction* OR adverse drug reaction* OR adverse outcome OR side effect OR side effects OR pharmacovigilance OR drug safety OR drug surveillance OR drug monitoring OR post marketing surveillance OR drug vigilance OR patient safety OR safety signal OR safety signals) AND (Electronic Health Record* OR electronic medical record*))

5. ACM Digital Library Search Strategy

[[Title: "electronic health record"] OR [Title: "electronic medical record"] OR [Title: "electronic medical records" "electronic health records"] OR [Title: "unstructured data"] OR [Title: "neural network"]] AND [[Title: "adverse drug effect"] OR [Title: "adverse drug effects"] OR [Title: "adverse drug event"] OR [Title: "adverse drug events"] OR [Title: "adverse drug reaction"] OR [Title: "adverse drug reactions"] OR [Title: "adverse drug outcome"] OR [Title: "adverse drug outcomes"] OR [Title: "drug side effect"] OR [Title: "drug side effects"]] AND [[Title: "pharmacovigilance"] OR [Title: "drug safety"] OR [Title: "drug surveillance"] OR [Title: "drug monitoring"] OR [Title: "post marketing surveillance"] OR [Title: "drug vigilance"] OR [Title: "patient safety"]] AND [E-Publication Date: (01/01/1990 TO 12/31/2023)]

6. Google Scholar

Search query date: 18 July 2023

"adverse events" AND "unstructured data" AND "electronic health records"

Excluded Studies

1. Al-Worafi YM. Technology for Drug Safety: Recommendations: Springer 2023:153-75.
2. Alagha MA, Young-Gough A, Lyndon M, et al. AIM and Patient Safety: Springer 2022:215-25.

3. Alfattni G, Belousov M, Peek N, Nenadic G. Extracting Drug Names and Associated Attributes From Discharge Summaries: Text Mining Study. *JMIR medical informatics* 2021;9(5):e24678. doi: <https://dx.doi.org/10.2196/24678>
4. Aronson JK. Artificial intelligence in pharmacovigilance: an introduction to terms, concepts, applications, and limitations. *Drug Saf* 2022;45(5):407-18.
5. Ball R, Dal Pan G. "Artificial intelligence" for pharmacovigilance: ready for prime time? *Drug Saf* 2022;45(5):429-38.
6. A Clustering Framework for Patient Phenotyping with Application to Adverse Drug Events; 2020.
7. Bate A, Hobbiger SF. Artificial intelligence, real-world automation and the safety of medicines. *Drug Saf* 2021;44:125-32.
8. Bate A, Luo Y. Artificial intelligence and machine learning for safe medicines. *Drug Saf* 2022;45(5):403-05.
9. Bhattacharya M. Applying machine learning methods to electronic health records: Studies in risk-stratification of chronic kidney disease and hypertrophic cardiomyopathy. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2019;80(8-B(E)):No-Specified.
10. Botsis T, Kreimeyer K. Improving drug safety with adverse event detection using natural language processing. *Expert Opin Drug Saf* 2023(just-accepted)
11. Chaichulee S, Promchai C, Kaewkomon T, et al. Multi-label classification of symptom terms from free-text bilingual adverse drug reaction reports using natural language processing. *PLoS One* 2022;17(8):e0270595. doi: <https://dx.doi.org/10.1371/journal.pone.0270595>
12. Chapman AB, Mowery DL, Swords DS, et al. Detecting Evidence of Intra-abdominal Surgical Site Infections from Radiology Reports Using Natural Language Processing. *AMIA Annual Symposium proceedings AMIA Symposium* 2017;2017(101209213):515-24.
13. Chapman AB, Peterson KS, Alba PR, et al. Detecting Adverse Drug Events with Rapidly Trained Classification Models. *Drug Saf* 2019;42(1):147-56. doi: <https://dx.doi.org/10.1007/s40264-018-0763-y>
14. Chazard E, Ficheur G, Bernonville S, et al. Data mining to generate adverse drug events detection rules. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society* 2011;15(6):823-30. doi: <https://dx.doi.org/10.1109/TITB.2011.2165727>
15. Chen L, Gu Y, Ji X, et al. Extracting medications and associated adverse drug events using a natural language processing system combining knowledge base and deep learning. *Journal of the American Medical Informatics Association : JAMIA* 2020;27(1):56-64. doi: <https://dx.doi.org/10.1093/jamia/ocz141>
16. Chen T, Dredze M, Weiner JP, et al. Extraction of Geriatric Syndromes From Electronic Health Record Clinical Notes: Assessment of Statistical Natural Language Processing Methods. *JMIR medical informatics* 2019;7(1):e13039. doi: <https://dx.doi.org/10.2196/13039>
17. Choudhury A, Asan O. Role of artificial intelligence in patient safety outcomes: systematic literature review. *JMIR medical informatics* 2020;8(7):e18599.
18. Chu J, Dong W, He K, et al. Using neural attention networks to detect adverse medical events from electronic health records. *J Biomed Inform* 2018;87(100970413, d2m):118-30. doi: <https://dx.doi.org/10.1016/j.jbi.2018.10.002>
19. Clapp MA, McCoy TH, Kim E, et al. Natural language processing of admission notes predicts severe maternal morbidity. *Am J Obstet Gynecol* 2022;226(1 Supplement):S320. doi: <https://dx.doi.org/10.1016/j.ajog.2021.11.539>
20. Coulet A, Shah NH, Wack M, et al. Predicting the need for a reduced drug dose, at first prescription. *Sci Rep* 2018;8(1):15558. doi: <https://dx.doi.org/10.1038/s41598-018-33980-0>
21. Explainable Predictions of Adverse Drug Events from Electronic Health Records Via Oracle Coaching; 2018.
22. Curino CA, Jia Y, Lambert B, et al. Mining Officially Unrecognized Side Effects of Drugs by Combining WebSearch and Machine Learning: Association for Computing Machinery, 2005:365–72.

23. Dandala B, Joopudi V, Devarakonda M. Adverse Drug Events Detection in Clinical Notes by Jointly Modeling Entities and Relations Using Neural Networks. *Drug Saf* 2019;42(1):135-46. doi: <https://dx.doi.org/10.1007/s40264-018-0764-x>
24. Dandala B, Joopudi V, Tsou C-H, et al. Extraction of Information Related to Drug Safety Surveillance From Electronic Health Record Notes: Joint Modeling of Entities and Relations Using Knowledge-Aware Neural Attentive Models. *JMIR medical informatics* 2020;8(7):e18417. doi: <https://dx.doi.org/10.2196/18417>
25. Daniel C, Kalra D. Clinical Research Informatics. *Yearb Med Inform* 2020;29(1):203-07. doi: <https://dx.doi.org/10.1055/s-0040-1702007>
26. Davies H, Noble P, Fins I, et al. A Method for Identification of Renal Disease in Unstructured Clinical Narratives. *Drug Saf* 2022;45(10):1135. doi: <https://dx.doi.org/10.1007/s40264-022-01219-7>
27. Davis SE, Zobotka L, Desai RJ, et al. Use of Electronic Health Record Data for Drug Safety Signal Identification: A Scoping Review. *Drug Saf* 2023;1-18.
28. Davoud SC, Kovacheva VP. On the Horizon: Specific Applications of Automation and Artificial Intelligence in Anesthesiology. *Current Anesthesiology Reports* 2023;13(2):31-40. doi: <https://dx.doi.org/10.1007/s40140-023-00558-0>
29. Deady M, Ezzeldin H, Cook K, et al. The Food and Drug Administration Biologics Effectiveness and Safety Initiative Facilitates Detection of Vaccine Administrations From Unstructured Data in Medical Records Through Natural Language Processing. *Frontiers in digital health* 2021;3(101771889):777905. doi: <https://dx.doi.org/10.3389/fdgth.2021.777905>
30. Del Rio-Bermudez C, Medrano IH, Yebes L, Poveda JL. Towards a symbiotic relationship between big data, artificial intelligence, and hospital pharmacy. *Journal of pharmaceutical policy and practice* 2020;13(1):75. doi: <https://dx.doi.org/10.1186/s40545-020-00276-6>
31. Despotou G, Korkontzelos I, Matragkas N, et al. Structuring Clinical Decision Support Rules for Drug Safety Using Natural Language Processing. *Stud Health Technol Inform* 2018;251(ck1, 9214582):89-92.
32. Ding Y, Tang J, Guo F. Identification of Drug-Side Effect Association via Semisupervised Model and Multiple Kernel Learning. *IEEE Journal of Biomedical and Health Informatics* 2019;23(6):2619-32. doi: 10.1109/JBHI.2018.2883834
33. Divya P, Susmita A, Sushmitha P, et al. Automation in pharmacovigilance: artificial intelligence and machinelearning for patient safety. *Journal of Innovations in Applied Pharmaceutical Science (JIAPS)* 2022;118-22.
34. Edrees H, Song W, Syrowatka A, et al. Intelligent telehealth in pharmacovigilance: a future perspective. *Drug Saf* 2022;45(5):449-58.
35. Eriksson R, Jensen PB, Frankild S, et al. Dictionary construction and identification of possible adverse drug events in Danish clinical narrative text. *Journal of the American Medical Informatics Association : JAMIA* 2013;20(5):947-53. doi: <https://dx.doi.org/10.1136/amiainl-2013-001708>
36. Eskildsen NK, Eriksson R, Christensen SB, et al. Implementation and comparison of two text mining methods with a standard pharmacovigilance method for signal detection of medication errors. *BMC Med Inform Decis Mak* 2020;20(1):1-11.
37. Flahault A, Salathe M. [Using big data for disease surveillance and drug safety monitoring]. *La Revue du praticien* 2017;67(1):25-30.
38. Florez E, Precioso F, Pighetti R, Riveill M. Deep Learning for Identification of Adverse Drug Reaction Relations: Association for Computing Machinery, 2019:149–53.
39. Discovering novel adverse drug events using natural language processing and mining of the electronic health record; 2009. Springer.
40. Fu S, Wyles CC, Osmon DR, et al. Automated Detection of Periprosthetic Joint Infections and Data Elements Using Natural Language Processing. *J Arthroplasty* 2021;36(2):688-92. doi: <https://dx.doi.org/10.1016/j.arth.2020.07.076>
41. Gahletia S, Gordon A. Big Data Analytics for Early Detection of Drug Safety Signals in Postmarketing Surveillance. *International Journal of Social Analytics* 2023;8(1):1-12.

42. Guan M. Machine Learning for Analyzing Drug Safety in Electronic Health Records: Springer 2023:595-610.
43. Hamid N, Portnoy JM, Pandya A. Computer-Assisted Clinical Diagnosis and Treatment. *Curr Allergy Asthma Rep* 2023(101096440) doi: <https://dx.doi.org/10.1007/s11882-023-01097-8>
44. Harpaz R, Haerian K, Chase HS, Friedman C. Mining Electronic Health Records for Adverse Drug Effects Using RegressionBased Methods: Association for Computing Machinery, 2010:100–07.
45. Hasanbaşoğlu M. Adverse Drug Events Discovery Using Natural Language Processing. *Artificial Intelligence* 2021
46. Hauben M. The Potential of Artificial Intelligence in Pharmacovigilance.
47. Henriksson A, Kvist M, Dalianis H, Duneld M. Identifying adverse drug event information in clinical notes with distributional semantic representations of context. *J Biomed Inform* 2015;57(100970413, d2m):333-49. doi: <https://dx.doi.org/10.1016/j.jbi.2015.08.013>
48. Hiremath BN, Patil MM. Enhancing optimized personalized therapy in clinical decision supportsystem using natural language processing. *Journal of King Saud University-Computer and Information Sciences* 2022;34(6):2840-48.
49. Honigman B, Light P, Pulling RM, Bates DW. A computerized method for identifying incidents associated with adverse drug events in outpatients. *Int J Med Inform* 2001;61(1):21-32. doi: <https://dx.doi.org/10.1016/S1386-5056%2800%2900131-3>
50. Hou X, You J, Hu P. Predicting Drug-Drug Interactions Using Deep Neural Network: Association for Computing Machinery, 2019:168–72.
51. Hu W, Wang SY. Predicting Glaucoma Progression Requiring Surgery Using Clinical Free-Text Notes and Transfer Learning With Transformers. *Translational Vision Science and Technology* 2022;11(3):37. doi: <https://dx.doi.org/10.1167/tvst.11.3.37>
52. Semantics-driven frequent data pattern mining on electronic health records for effective adverse drug event monitoring; 2013.
53. Ibrahim H, Abdo A, El Kerdawy AM, Eldin AS. Signal detection in pharmacovigilance: a review of informatics-drivenapproaches for the discovery of drug-drug interaction signals in differentdata sources. *Artificial Intelligence in the Life Sciences* 2021;1:100005.
54. Inglis JM, Bacchi S, Troelnikov A, et al. Automation of penicillin adverse drug reaction categorisation and risk stratification with machine learning natural language processing. *Int J Med Inform* 2021;156(ct4, 9711057):104611. doi: <https://dx.doi.org/10.1016/j.ijmedinf.2021.104611>
55. Injeti N, Pal A. Adverse Drug Reaction Monitoring: Pharmacovigilance and ArtificialIntelligence. *International Journal of Pharmaceutical Research (09752366)* 2021;13(2)
56. Iqbal E, Mallah R, Jackson RG, et al. Identification of Adverse Drug Events from Free Text Electronic Patient Records and Information in a Large Mental Health Case Register. *PLoS One* 2015;10(8):e0134208. doi: <https://dx.doi.org/10.1371/journal.pone.0134208>
57. Detecting Adverse Drug Reaction with Data Mining And Predicting its Severity With Machine Learning; 2018.
58. Iyer SV, Harpaz R, LePendur P, et al. Mining clinical text for signals of adverse drug-drug interactions. *Journal of the American Medical Informatics Association : JAMIA* 2014;21(2):353-62. doi: <https://dx.doi.org/10.1136/amiajnl-2013-001612>
59. Izquierdo JL, Almonacid C, Campos C, et al. Systemic Corticosteroids in Patients with Bronchial Asthma: A Real-Life Study. *J Investig Allergol Clin Immunol* 2021(9107858, byj, 9107858):0. doi: <https://dx.doi.org/10.18176/jiaci.0765>
60. Jagannatha A, Liu F, Liu W, Yu H. Overview of the First Natural Language Processing Challenge for Extracting Medication, Indication, and Adverse Drug Events from Electronic Health Record Notes (MADE 1.0). *Drug Saf* 2019;42(1):99-111. doi: <https://dx.doi.org/10.1007/s40264-018-0762-z>
61. A Pharmaceutical Intelligent Information System to detect allergies and Adverse Drugs Reactions based on internet of things; 2010.

62. Jeon E, Kim Y, Park H, et al. Analysis of Adverse Drug Reactions Identified in Nursing Notes Using Reinforcement Learning. *Healthcare informatics research* 2020;26(2):104-11. doi: <https://dx.doi.org/10.4258/hir.2020.26.2.104>
63. A High Performance Agent-Based System for Reporting Suspected Adverse Drug Reactions; 2012.
64. Ji Y, Ying H, Dews P, et al. A Potential Causal Association Mining Algorithm for Screening Adverse Drug Reactions in Postmarketing Surveillance. *IEEE Trans Inf Technol Biomed* 2011;15(3):428-37. doi: 10.1109/TITB.2011.2131669
65. An exclusive causal-leverage measure for detecting adverse drug reactions from electronic medical records; 2011.
66. Identifying Unknown Adverse Drug Reaction Signal Pairs in Postmarketing Surveillance Using an Active Multi-agent System Approach; 2008.
67. Ji Y, Ying H, Farber MS, et al. A Distributed, Collaborative Intelligent Agent System Approach for Proactive Postmarketing Drug Safety Surveillance. *IEEE Trans Inf Technol Biomed* 2010;14(3):826-37. doi: 10.1109/TITB.2009.2037007
68. Mining Infrequent Causal Associations in Electronic Health Databases; 2011.
69. Ji Y, Ying H, Tran J, et al. A Method for Mining Infrequent Causal Associations and Its Application in Finding Adverse Drug Reaction Signal Pairs. *IEEE Transactions on Knowledge and Data Engineering* 2013;25(4):721-33. doi: 10.1109/TKDE.2012.28
70. A temporal interestingness measure for drug interaction signal detection in post-marketing surveillance; 2014.
71. Jia K. Machine Learning on Mining Potential Adverse Drug Reactions for Pharmacovigilance: Association for Computing Machinery, 2021:295–98.
72. Jin Y, Li F, Vimalananda VG, Yu H. Automatic Detection of Hypoglycemic Events From the Electronic Health Record Notes of Diabetes Patients: Empirical Study. *JMIR medical informatics* 2019;7(4):e14340. doi: <https://dx.doi.org/10.2196/14340>
73. Ju M, Nguyen NTH, Miwa M, Ananiadou S. An ensemble of neural models for nested adverse drug events and medication extraction with subwords. *Journal of the American Medical Informatics Association : JAMIA* 2020;27(1):22-30. doi: <https://dx.doi.org/10.1093/jamia/ocz075>
74. Karhade AV, Lavoie-Gagne O, Agaronnik N, et al. Natural language processing for prediction of readmission in posterior lumbar fusion patients: which free-text notes have the most utility? *The spine journal : official journal of the North American Spine Society* 2022;22(2):272-77. doi: <https://dx.doi.org/10.1016/j.spinee.2021.08.002>
75. Karimi S, Wang C, Metke-Jimenez A, et al. Text and data mining techniques in adverse drug reaction detection. *ACM Computing Surveys (CSUR)* 2015;47(4):1-39.
76. Dimensionality Reduction with Random Indexing: An Application on Adverse Drug Event Detection Using Electronic Health Records; 2014.
77. Kassekert R, Grabowski N, Lorenz D, et al. Industry perspective on artificial intelligence/machine learning in pharmacovigilance. *Drug Saf* 2022;45(5):439-48.
78. Detecting Potential Adverse Drug Reactions of Preschool ADHD Treatment Using Health Consumer-Generated Content; 2020.
79. Kompa B, Hakim JB, Palepu A, et al. Artificial intelligence based on machine learning in pharmacovigilance: ascopying review. *Drug Saf* 2022;45(5):477-91.
80. Kumar Attar R, Komal. The Emergence of Natural Language Processing (NLP) Techniques in Healthcare AI: Springer 2022:285-307.
81. Detection of Drug-Associated Rhabdomyolysis Through Data Mining Techniques; 2020.
82. Lee S, Kim S, Lee J, et al. Explainable Artificial Intelligence for Patient Safety: A Review of Application in Pharmacovigilance. *IEEE Access* 2023
83. Minitrack: Consumer Health Informatics, Patient Safety and Quality of Practice; 2007.
84. Létinier L, Jouganous J, Benkebil M, et al. Artificial intelligence for unstructured healthcare data: application to coding of patient reporting of adverse drug reactions. *Clin Pharmacol Ther* 2021;110(2):392-400.

85. Li F, Liu W, Yu H. Extraction of Information Related to Adverse Drug Events from Electronic Health Record Notes: Design of an End-to-End Model Based on Deep Learning. *JMIR medical informatics* 2018;6(4):e12159. doi: <https://dx.doi.org/10.2196/12159>
86. Li R, Hu B, Liu F, et al. Detection of Bleeding Events in Electronic Health Record Notes Using Convolutional Neural Network Models Enhanced With Recurrent Neural Network Autoencoders: Deep Learning Approach. *JMIR medical informatics* 2019;7(1):e10788. doi: <https://dx.doi.org/10.2196/10788>
87. Li Y. Combining Heterogeneous Databases to Detect Adverse Drug Reactions: Columbia University 2015.
88. Liang J, Xian X, He X, et al. A Novel Approach towards Medical Entity Recognition in Chinese Clinical Text. *J Healthc Eng* 2017;2017(101528166):4898963. doi: <https://dx.doi.org/10.1155/2017/4898963>
89. Liang L, Hu J, Sun G, et al. Artificial intelligence-based pharmacovigilance in the setting of limited resources. *Drug Saf* 2022;45(5):511-19.
90. Lin TC, Cai T, Kane-Wanger G, et al. Utilizing natural language processing to examine the risk of arthralgia between vedolizumab and tumor necrosis factor inhibitors in inflammatory bowel disease. *Pharmacoepidemiol Drug Saf* 2017;26(Supplement 2):35-36. doi: <https://dx.doi.org/10.1002/pds.4275>
91. Liu F, Jagannatha A, Yu H. Towards drug safety surveillance and pharmacovigilance: current progress in detecting medication and adverse drug events from electronic health records. *Drug Saf* 2019;42(1):95-97.
92. Liu F, Pradhan R, Druhl E, et al. Learning to detect and understand drug discontinuation events from clinical narratives. *Journal of the American Medical Informatics Association : JAMIA* 2019;26(10):943-51. doi: <https://dx.doi.org/10.1093/jamia/ocz048>
93. Liu M, Hu Y, Tang B. Role of text mining in early identification of potential drug safety issues. *Methods in molecular biology (Clifton, NJ)* 2014;1159(bu3, 9214969):227-51. doi: https://dx.doi.org/10.1007/978-1-4939-0709-0_13
94. Detecting Adverse Drug Reactions Using Inpatient Medication Orders and Laboratory Tests Data; 2012.
95. Liu X. Health data analytics: Data and text mining approaches for pharmacovigilance. *Dissertation Abstracts International Section A: Humanities and Social Sciences* 2017;77(12-A(E)):No-Specified.
96. Mining Adverse Drug Reactions from Electronic Health Records; 2013.
97. Luo Y, Thompson WK, Herr TM, et al. Natural Language Processing for EHR-Based Pharmacovigilance: A Structured Review. *Drug Saf* 2017;40(11):1075-89. doi: <https://dx.doi.org/10.1007/s40264-017-0558-6>
98. Ma M, Lee K, Mai Y, et al. Extracting longitudinal anticancer treatments at scale using deep natural language processing and temporal reasoning. *J Clin Oncol* 2021;39(15 SUPPL) doi: https://dx.doi.org/10.1200/JCO.2021.39.15_suppl.e18747
99. Martin GL, Jouganous J, Savidan R, et al. Validation of artificial intelligence to support the automatic coding of patient adverse drug reaction reports, using nationwide pharmacovigilance data. *Drug Saf* 2022;45(5):535-48.
100. Melton BL. Methods for the detection of drug-drug interactions in text. *European Pharmaceutical Review* 2015;20(4):20-21.
101. Mitra A, Rawat BPS, McManus D, et al. Bleeding Entity Recognition in Electronic Health Records: A Comprehensive Analysis of End-to-End Systems. *AMIA Annual Symposium proceedings AMIA Symposium* 2020;2020(101209213):860-69.
102. Munkhdalai T, Liu F, Yu H. Clinical Relation Extraction Toward Drug Safety Surveillance Using Electronic Health Record Narratives: Classical Learning Versus Deep Learning. *JMIR public health and surveillance* 2018;4(2):e29. doi: <https://dx.doi.org/10.2196/publichealth.9361>
103. Munsaka M, Liu M, Xing Y, Yang H. Leveraging Machine Learning, Natural Language Processing, and Deep Learning in Drug Safety and Pharmacovigilance: Chapman and Hall/CRC 2022:193-229.

104. Murali K, Kaur S, Prakash A, Medhi B. Artificial intelligence in pharmacovigilance: Practical utility. *Indian J Pharmacol* 2019;51(6):373.
105. Murphy RM, Klopotoska JE, de Keizer NF, et al. Adverse drug event detection using natural language processing: A scoping review of supervised learning methods. *PLoS One* 2023;18(1):e0279842. doi: <https://dx.doi.org/10.1371/journal.pone.0279842>
106. Nikfarjam A, Ransohoff JD, Callahan A, et al. Early detection of adverse drug reactions in social health networks: a natural language processing pipeline for signal detection. *JMIR public health and surveillance* 2019;5(2):e11264.
107. Noren N. Needles in hay-use of machine learning to identify references to drugs and adverse events in social media. *Drug Saf* 2017;40(10):1037-38. doi: <https://dx.doi.org/10.1007/s40264-017-0580-8>
108. Nugmanov R, Alimova I, Tutubalina E. Adverse drug reactions identification in social media posts and electronic health records with neural networks. *Eur J Clin Invest* 2019;49(Supplement 1):116-17. doi: <https://dx.doi.org/10.1111/eci.13109>
109. Oleg R, Nicholas M, David S, Arun A. DATA ANALYSIS AND MACHINE LEARNING EFFORT IN HEALTHCARE: Wiley 2017:295-328.
110. Ortega C, Lo YC, Blackley S, et al. Methods for Identifying and Reconciling Allergy Information in the Electronic Health Record. *J Allergy Clin Immunol* 2021;147(2 Supplement):AB168. doi: <https://dx.doi.org/10.1016/j.jaci.2020.12.597>
111. Pandey V, Fozia Khanum A, Singhal M, et al. REVOLUTIONIZING DRUG SAFETY: THE ROLE OF AI IN PHARMACOVIGILANCE. 2023
112. Pilipiec P. Using Machine Learning to Understand Text for Pharmacovigilance: A Systematic Review. 2021
113. Pilipiec P, Liwicki M, Bota A. Using machine learning for pharmacovigilance: a systematic review. *Pharmaceutics* 2022;14(2):266.
114. Prabhakaran S, Hong HJ. Artificial intelligence methodology in clinical research: Elsevier 2023:395-402.
115. Pradhan R, Liu W, Gurwitz J, Yu H. Automatically identifying prescribing cascades in clinical notes using natural language processing. *Pharmacoepidemiol Drug Saf* 2018;27(Supplement 2):464. doi: <https://dx.doi.org/10.1002/pds.4629>
116. Raja K, Jonnalagadda S. Natural Language Processing and Data Mining for Clinical Text. *Healthcare Data Analytics* 2015;36:219.
117. Ranganatha AM. Biomedical information extraction pipelines for public health in the age of deep learning. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2020;81(7-B):No-Specified.
118. Rochefort C, Verma A, Egualé T, Buckeridge D. Surveillance of adverse events in elderly patients: A study on the accuracy of applying natural language processing techniques to electronic health record data. *Eur Geriatr Med* 2015;6(SUPPL. 1):S15.
119. Rochefort CM. Novel methods of adverse event detection using electronic health record data: A critical review of the literature. *Pharmacoepidemiol Drug Saf* 2014;23(SUPPL. 1):126. doi: <https://dx.doi.org/10.1002/pds.3701>
120. Rochefort CM, Verma AD, Egualé T, et al. A novel method of adverse event detection can accurately identify venous thromboembolisms (VTEs) from narrative electronic health record data. *Journal of the American Medical Informatics Association : JAMIA* 2015;22(1):155-65. doi: <https://dx.doi.org/10.1136/amiajnl-2014-002768>
121. Ross EG, Leeper N, Shah N. Use of machine learning to accurately predict adverse events in patients with peripheral artery disease using electronic health record data. *Arterioscler Thromb Vasc Biol* 2016;36(Supplement 1)
122. Salas M, Petracek J, Yalamanchili P, et al. The Use of Artificial Intelligence in Pharmacovigilance: A Systematic Review of the Literature. *Pharmaceut Med* 2022;36(5):295-306.

123. Salathe M. Digital Pharmacovigilance and Disease Surveillance: Combining Traditional and Big-Data Systems for Better Public Health. *The Journal of infectious diseases* 2016;214(suppl_4):S399-S403. doi: <https://dx.doi.org/10.1093/infdis/jiw281>
124. Salvo F, Micallef J, Lahouegue A, et al. Will the future of pharmacovigilance be more automated? *Expert Opin Drug Saf* 2023;1-8.
125. Fall Detection in Clinical Notes using Language Models and Token Classifier; 2020.
126. Sanyal J, Rubin D, Banerjee I. A weakly supervised model for the automated detection of adverse events using clinical notes. *J Biomed Inform* 2022;126(100970413, d2m):103969. doi: <https://dx.doi.org/10.1016/j.jbi.2021.103969>
127. Application of Machine Learning and Big data Analytics in Pharmacovigilance and Drug Safety; 2019. IEEE.
128. Sarraju A, Coquet J, Chan A, et al. IDENTIFYING REASONS FOR STATIN NONADHERENCE IN A DIVERSE, REAL-WORLD POPULATION USING ELECTRONIC HEALTH RECORDS AND NATURAL LANGUAGE PROCESSING. *J Am Coll Cardiol* 2021;77(18 Supplement 1):1665. doi: <https://dx.doi.org/10.1016/S0735-1097%2821%2903021-7>
129. Sarraju A, Coquet J, Zammit A, et al. Using deep learning-based natural language processing to identify reasons for statin nonuse in patients with atherosclerotic cardiovascular disease. *Communications medicine* 2022;2(9918250414506676):88. doi: <https://dx.doi.org/10.1038/s43856-022-00157-w>
130. Schmider J, Kumar K, LaForest C, et al. Innovation in pharmacovigilance: use of artificial intelligence in adverse event case processing. *Clin Pharmacol Ther* 2019;105(4):954-61.
131. Segura-Bedmar I, Martínez Fernández P. Pharmacovigilance through the development of text mining and natural language processing techniques. 2015
132. Sethi T, Shah NH. Pharmacovigilance using textual data: The need to go deeper and wider into the content (text). *Drug Saf* 2017;40:1047-48.
133. Prediction of Adverse Effects of Medical Treatment using Electronic Health Record and Machine Learning; 2021.
134. Sohn S, Kocher J-PA, Chute CG, Savova GK. Drug side effect extraction from clinical narratives of psychiatry and psychology patients. *Journal of the American Medical Informatics Association : JAMIA* 2011;18 Suppl 1(b92, 9430800):i144-9. doi: <https://dx.doi.org/10.1136/amiajnl-2011-000351>
135. Sohn S, Kocher JPA, Chute CG, Savova GK. Drug side effect extraction from clinical narratives of psychiatry and psychology patients. *J Am Med Inform Assoc* 2011;18(SUPPL. 1):144-49. doi: <https://dx.doi.org/10.1136/amiajnl-2011-000351>
136. Sorup FKH, Brunak S, Eriksson R. Association between antipsychotic drug dose and length of clinical notes: a proxy of disease severity? *BMC Med Res Methodol* 2020;20(1):107. doi: <https://dx.doi.org/10.1186/s12874-020-00993-1>
137. Sorup FKH, Eriksson R, Westergaard D, et al. Sex differences in text-mined possible adverse drug events associated with drugs for psychosis. *Journal of Psychopharmacology* 2020;34(5):532-39. doi: <https://dx.doi.org/10.1177/0269881120903466>
138. Stetson PD, Johnson SB, Scotch M, Hripcsak G. The sublanguage of cross-coverage. *Proceedings AMIA Symposium* 2002(100883449):742-6.
139. Accurate and Safe Drug Recommendations based on Singular Value Decomposition; 2023.
140. Taewijit S, Theeramunkong T, Ikeda M. Distant Supervision with Transductive Learning for Adverse Drug Reaction Identification from Electronic Medical Records. *J Healthc Eng* 2017;2017(101528166):7575280. doi: <https://dx.doi.org/10.1155/2017/7575280>
141. Tamijeselman S, Praveena A, Surekha S, Vayaravel CA. Artificial Intelligence's Role in Healthcare.
142. Tang H, Solti I, Kirkendall E, et al. Leveraging Food and Drug Administration Adverse Event Reports for the Automated Monitoring of Electronic Health Records in a Pediatric Hospital. *Biomed Inform Insights* 2017;9(101512875):1178222617713018. doi: <https://dx.doi.org/10.1177/1178222617713018>

143. Tang Y, Yang J, Ang PS, et al. Detecting adverse drug reactions in discharge summaries of electronic medical records using Readpeer. *Int J Med Inform* 2019;128(ct4, 9711057):62-70. doi: <https://dx.doi.org/10.1016/j.ijmedinf.2019.04.017>
144. Togra A, Pawar S. Role of automation, natural language processing, artificial intelligence, and machine learning in hospital settings to identify and prevent adverse drug reactions. *Journal of Pharmacovigilance and Drug Research* 2022;3(3):3-5.
145. Trifirò G, Crisafulli S. A new era of pharmacovigilance: Future challenges and opportunities. *Frontiers in Drug Safety and Regulation* 2022;2:1.
146. Detection of adverse drug events through data mining techniques; 2015.
147. Ventola CL. Big data and pharmacovigilance: data mining for adverse drug events and interactions. *Pharmacy and therapeutics* 2018;43(6):340.
148. Verman S, Anjankar A. A Narrative Review of Adverse Event Detection, Monitoring, and Prevention in Indian Hospitals. *Cureus* 2022;14(9):e29162. doi: <https://dx.doi.org/10.7759/cureus.29162>
149. Vilar S, Friedman C, Hripcsak G. Detection of drug-drug interactions through data mining studies using clinical sources, scientific literature and social media. *Brief Bioinform* 2018;19(5):863-77. doi: <https://dx.doi.org/10.1093/bib/bbx010>
150. Wang FT, Song J, Lin ND. Characterization of potential serious allergic reactions using data from natural language processing (NLP) within an electronic health record (EHR) based system. *Pharmacoepidemiol Drug Saf* 2017;26(Supplement 2):37-38. doi: <https://dx.doi.org/10.1002/pds.4275>
151. Wang G, Jung K, Winnenburg R, Shah NH. A method for systematic discovery of adverse drug events from clinical notes. *Journal of the American Medical Informatics Association : JAMIA* 2015;22(6):1196-204. doi: <https://dx.doi.org/10.1093/jamia/ocv102>
152. Wang X. A framework of quantitative pharmacovigilance using natural language processing, statistics and electronic health records. *Dissertation Abstracts International: Section B: The Sciences and Engineering* 2011;72(5-B):2738.
153. Wang X, Hripcsak G, Markatou M, Friedman C. Active computerized pharmacovigilance using natural language processing, statistics, and electronic health records: a feasibility study. *Journal of the American Medical Informatics Association : JAMIA* 2009;16(3):328-37. doi: <https://dx.doi.org/10.1197/jamia.M3028>
154. Wani P, Shelke A, Marwadi M, et al. ROLE OF ARTIFICIAL INTELLIGENCE IN PHARMACOVIGILANCE: A CONCISE REVIEW. *Journal of Pharmaceutical Negative Results* 2022:6149-56.
155. Warrer P, Hansen EH, Juhl-Jensen L, Aagaard L. Using text-mining techniques in electronic patient records to identify ADRs from medicine use. *Br J Clin Pharmacol* 2012;73(5):674-84. doi: <https://dx.doi.org/10.1111/j.1365-2125.2011.04153.x>
156. Wasylewicz A, van de Burgt B, Weterings A, et al. Identifying adverse drug reactions from free-text electronic hospital health record notes. *Br J Clin Pharmacol* 2022;88(3):1235-45. doi: <https://dx.doi.org/10.1111/bcp.15068>
157. Wong A, Plasek JM, Montecalvo SP, Zhou L. Natural Language Processing and Its Implications for the Future of Medication Safety: A Narrative Review of Recent Advances and Challenges. *Pharmacotherapy* 2018;38(8):822-41. doi: <https://dx.doi.org/10.1002/phar.2151>
158. Wu H, Ji J, Tian H, et al. Chinese-Named Entity Recognition From Adverse Drug Event Records: Radical Embedding-Combined Dynamic Embedding-Based BERT in a Bidirectional Long Short-term Conditional Random Field (Bi-LSTM-CRF) Model. *JMIR medical informatics* 2021;9(12):e26407. doi: <https://dx.doi.org/10.2196/26407>
159. Wunnava S, Qin X, Kakar T, et al. Adverse Drug Event Detection from Electronic Health Records Using Hierarchical Recurrent Neural Networks with Dual-Level Embedding. *Drug Saf* 2019;42(1):113-22. doi: <https://dx.doi.org/10.1007/s40264-018-0765-9>
160. Xu H, Stenner SP, Doan S, et al. MedEx: A medication information extraction system for clinical narratives. *J Am Med Inform Assoc* 2010;17(1):19-24. doi: <https://dx.doi.org/10.1197/jamia.M3378>

161. Extraction of Clinical Phenotypic Information from Online Heterogeneous Healthcare Networks; 2015.
162. Yang H. Drug safety signal detection from online health communities. *Dissertation Abstracts International Section A: Humanities and Social Sciences* 2017;78(1-A(E)):No-Specified.
163. Discovering Drug-Drug Interactions and Associated Adverse Drug Reactions with Triad Prediction in Heterogeneous Healthcare Networks; 2016.
164. Yang X, Bian J, Fang R, et al. Identifying relations of medications with adverse drug events using recurrent convolutional neural networks and gradient boosting. *Journal of the American Medical Informatics Association : JAMIA* 2020;27(1):65-72. doi: <https://dx.doi.org/10.1093/jamia/ocz144>
165. Yang X, Bian J, Gong Y, et al. MADEx: A System for Detecting Medications, Adverse Drug Events, and Their Relations from Clinical Notes. *Drug Saf* 2019;42(1):123-33. doi: <https://dx.doi.org/10.1007/s40264-018-0761-0>
166. Young IJB, Luz S, Lone N. A systematic review of natural language processing for classification tasks in the field of incident reporting and adverse event analysis. *Int J Med Inform* 2019;132(ct4, 9711057):103971. doi: <https://dx.doi.org/10.1016/j.ijmedinf.2019.103971>
167. Identify Cancer Patients at Risk for Heart Failure using Electronic Health Record and Genetic Data; 2022.
168. Detecting Potential Serious Adverse Drug Reactions Using Sequential Pattern Mining Method; 2018.
169. Zhang W, Kuang Z, Peissig P, Page D. Adverse Drug Reaction Discovery from Electronic Health Records with DeepNeural Networks: Association for Computing Machinery, 2020:30–39.
170. Comparing Pharmacovigilance Outcomes Between FAERS and EMR Data for Acute Mania Patients; 2018.
171. Zhao YX, Yuan H, Wu Y. Prediction of Adverse Drug Reaction Using Machine Learning and DeepLearning Based on an Imbalanced Electronic Medical Records Dataset: Association for Computing Machinery, 2021:17–21.
172. Zhou B, Yang G, Shi Z, Ma S. Natural language processing for smart healthcare. *IEEE Rev Biomed Eng* 2022
173. Zitu MM, Zhang S, Owen DH, et al. Generalizability of machine learning methods in detecting adverse drug events from clinical narratives in electronic medical records. *Front Pharmacol* 2023;14(101548923):1218679. doi: <https://dx.doi.org/10.3389/fphar.2023.1218679>
174. Zou C. Analyzing research trends on drug safety using topic modeling. *Expert Opin Drug Saf* 2018;17(6):629-36. doi: <https://dx.doi.org/10.1080/14740338.2018.1458838>